Phonological Functions of Facial Movements:

Evidence from deaf users of German Sign Language

A Dissertation

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Eeva A. Elliott

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As the infamous geophysicist says – "[…] alles anders; unnoetig!"

Summary

In this dissertation I address the issue of how facial movements are used by deaf signers of German Sign Language (Deutsche Gebärdensprache; DGS) at the lexical and sub-lexical level. Although it is an empirical fact that signers of various signed languages make facial movements that have scope over only single lexical items, currently there is no consensus on how these movements should be accounted for in linguistic theory, because many of the facial movements occurring at this level do not fit neatly into the preexisting linguistic constructs 'phoneme' or 'morpheme'. The move that is taken by most theorists in order to account for these facial elements is to propose that there are at least two very distinct phenomena that occur at this level each requiring a different model to account for its use. The facial movements that fit well with the widely accepted definition of 'morpheme' are dealt with by existing morpho-syntactic theories, the facial movements that fit well with the widely accepted definition of 'phoneme' can be dealt with by existing phonological theories, while those that seem to behave a bit like a phoneme and a bit like a morpheme are accounted for with special frameworks or are deemed 'extra linguistic', therefore not requiring linguistic explanation at all (Boyes Braem & Sutton-Spence, 2001).

Although facial movements with scope over single lexical items vary on the following dimensions: which facial muscles are used i.e. mouth, upper face, or whole face; their origin i.e. derived from ambient spoken languages or derived within signed languages, and whether they seem to add semantic information or not, I regard them as essentially the same general phenomenon in contrast to most current accounts. I claim that they are phonological features with some semantic properties. In order to make this claim a relaxation of the principle of duality of patterning is required. The term 'duality of patterning' is usually understood to mean that phonemes are discrete meaningless units and that all languages can be broken down to the level of meaningless units. However, recent research indicates that rather than being a universal duality of patterning may be more of a statistical tendency (Blevins, 2012). The definition of phoneme then that I adopt is: a phoneme is a unit whose function is to provide distinctive perceptual cues to allow receivers to distinguish between elements in the communicated signal. Whether this unit is associated with a meaning or not does not contradict the claim that it also functions to create perceptually salient oppositions in the communicated signal.

In this dissertation I have conducted two studies on two types of facial movements with scope over single lexical items: mouthings and expressions of disgust. In my first study, I applied the claim that mouthings are phonological elements to the issue of how deaf people read German (Elliott, Braun, Kuhlmann, & Jacobs, 2012). In my second study, I attempt to establish whether facial expressions from the domain of emotions are used as phonological elements (Elliott & Jacobs, 2013; Elliott & Jacobs, submitted).

In the literature on how deaf individuals read there has long been a debate over whether they access phonology when reading and whether this plays a role in their reading achievement. This is of practical importance, since deaf individuals on average do not achieve the same level of reading proficiency as their hearing peers (Traxler, 2000). In comparison to the literature on hearing reading, the debate so far has remained theoretically unspecific regarding

two crucial points: 1) the phonological units deaf individuals may have of oral language have not been specified 2) there seem to be no explicit cognitive models specifying how phonology and other factors operate in reading by deaf individuals. Drawing on the hearing reading literature (Braun, Hutzler, Ziegler, Dambacher, & Jacobs, 2009; Briesemeister et al., 2009; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Jacobs & Grainger, 1994) I propose that deaf individuals have representations of the sub-lexical structure of oral-aural language which are based on mouth shapes, and that these sub-lexical units are activated during reading by deaf individuals. I specify the sub-lexical units as 11 'visemes' (mouthings) and I specify their role in reading by adapting the Dual Route Cascaded Model of Reading (Coltheart et al., 2001) to my viseme set. I assessed the indirect route of this model by investigating whether deaf individuals would display the 'pseudo-homoviseme' effect during a lexical decision task. I found a main effect of pseudo-homovisemy suggesting that at least some deaf individuals do automatically access sub-lexical structure during single word reading.

To the best of my knowledge this study was the first to specify possible sub-lexical units of deaf readers and to test their psychological validity in a lexical decision task using a standard reaction time paradigm of the word recognition literature for hearing persons. The obtained pseudo-homovisemy effect suggests that sub-lexical units, in the form of visemes, could indeed be automatically accessed by some deaf individuals during reading. However, further work on identifying the exact units and assessing individual differences amongst deaf readers in their use, needs to be carried out. For example, we defined the viseme set based on visual features, not on tactile ones. It is plausible that deaf individuals have more visemic distinctions than presented in this inventory if tactile features are taken into consideration.

In my second study I wished to establish whether emotion related expressions are used as phonological units by deaf signers of German Sign Language. It has been observed that signs for emotion concepts in American Sign Language (ASL) such as sad (Reilly, McIntire, & Bellugi, 1990) are produced with a facial expression that corresponds in meaning to the emotion concept. In the literature, this type of facial expression is often regarded as a phonological feature rather than a morpheme, since they occur on single lexical items but unlike facial adverbials they are not systematically used to modify the meaning of entire classes of signs. However, these facial expressions have not been well studied, for example to the best of my knowledge there are as yet no corpus studies that confirm their scope or provide data on their frequency and distribution, and so their linguistic function, i.e. whether they are best regarded as phonological features, morphemes, or something else, is not altogether clear.

I found evidence that an emotion related facial expression is consistently used with the sign EKEL 'disgust'. I found that it has scope over the lexical item. Using the Facial Action Coding System developed by Ekman et al. (2002b) I further established that there is a certain degree of idiosyncrasy in exactly how the facial expression is produced although the most common form was mouth opening and tongue protrusion. In trying to account for the function of the facial expression either phonologically or morphologically, one runs into the problem of apparent redundancy. This is the same problem one has in accounting for how mouthings are used in German Sign Language. Phonologically they seem redundant because the manual component of signs is usually distinct enough not to require additional features, and

morphologically emotion related facial expressions and mouthings do not add new semantic content to the sign, they seem to only repeat the semantic content of the manual component. Following the Zipfian notion of least effort (Zipf, [1949] 2012), I propose that this redundancy is only apparent. The use of emotion related facial expressions and mouthings must be of benefit to the receiver of the message, or else the sender would not make the extra effort to use additional articulators. This hypothesis can be tested in future psycholinguistic studies.

Given the shared properties between emotion related facial expression, mouthings, and other facial movements at the lexical level, namely that they have scope usually over single lexical items, that they have some degree of semantic content, and that the display varying degrees of independence in relation the manual component of a sign, we regard them as belonging to one class of phenomena that vary in (1) their origin and (2) their location on a phonological-morphological continuum. I propose that this class be regarded as an additional layer of communication that functions like a parallel lexicon to the manual component in DGS. The relationship between this layer and manual lexical items is analogous in some ways to the relationship between gesture and words, or intonation and words. Overall, the present results indicate that deaf signers use facial movements as phonological units.

Zusammenfassung

In dieser Dissertation behandele ich das Thema, wie Gesichtsbewegungen von gehörlosen Sprechern der Deutschen Gebärdensprache (DGS) auf der lexikalischen und sublexikalischen Ebene benutzt werden. Obwohl es eine empirische Tatsache ist, dass Sprecher unterschiedlicher Gebärdensprachen Gesichtsbewegungen machen, die nur einzelne lexikalische Einheiten umfassen, gibt es derzeit keine Übereinstimmung darüber, wie diese Bewegungen in der linguistischen Theorie erklärt werden sollen. Dies liegt daran, dass viele der Gesichtsbewegungen, die auf dieser Ebene geschehen, nicht nahtlos in die schon existierenden linguistischen Konstrukte "Phoneme" oder "Morpheme" passen. Was die meisten Theoretiker versucht haben, um diese Gesichtselemente zu erklären, war der Vorschlag, dass es wenigstens zwei sehr unterschiedliche, auf dieser Ebene geschehende Phänomene gibt, von denen jeder ein anderes Modell erfordert, dass seinen Gebrauch rechtfertigen würde. Gesichtsbewegungen, die zu der von vielen anerkannte Definition von "Morphem" passen, sind von den existierenden morphosyntaktischen Theorien aufgegriffen; Gesichtsbewegungen, die in die von vielen anerkannte Definition von "Phonem" passen, können durch existierende phonologische Theorien aufgegriffen werden; und diejenigen Gesichtsbewegungen letztendlich, die sich ein wenig wie Phoneme und ein wenig wie Morpheme zu verhalten scheinen, werden von speziellen Referenzsystemen aufgegriffen oder als "extralinguistisch" erachtet, weshalb sie keinerlei linguistischer Erklärung erfordern (Boyes Braem & Sutton-Spence, 2001).

Obwohl Gesichtsbewegungen mit dem Zeitumfang einzelner lexikalischer Einheiten variieren, und zwar in folgenden Dimensionen: erstens welche Gesichtsmuskel gebraucht werden, z.B. im Mund, im oberen Teil des Gesichts, oder im ganzen Gesicht; zweitens in Bezug auf ihre Herkunft, d.h. ob sie von den in der Umgebung gesprochenen Sprachen abgeleitet sind oder ob ihre Ableitung innerhalb der Gebärdensprachen stattfand, und drittens ob sie semantische Information hinzuzufügen scheinen oder nicht, halte ich sie als im Wesentlichen für dasselbe allgemeine Phänomen, in Abgrenzung zu den meisten gegenwärtigen Ansätzen. Ich behaupte, dass sie phonologische Merkmale mit einigen semantischen Merkmalen sind. Um diese Behauptung aufstellen zu können, ist eine Auflockerung des Prinzips der zweifachen Gliederung erforderlich. Die Bedeutung des Begriffs "zweifache Gliederung" ist meistens so verstanden, dass Phoneme diskrete bedeutungslose Einheiten sind und dass alle Sprachen auf die Ebene der bedeutungslosen Einheiten heruntergebrochen werden können. Jüngste Forschungen haben jedoch erwiesen, dass zweifache Gliederung - statt eine universelle - eine eher statistische Tendenz zu sein scheint (Blevins, 2012). Daher ist die Definition von Phonem, die ich vorschlage, wie folgt: Ein Phonem ist eine Einheit, deren Funktion ist, distinktive Wahrnehmungshinweise bereitzustellen, um dem Empfänger zu ermöglichen, zwischen den Elementen im kommunizierten Signal unterscheiden zu können. Ob diese Einheit mit einer Bedeutung assoziiert ist oder nicht, widerspricht nicht der Behauptung, dass sie auch dazu dient, wahrnehmbare auffallende Gegensätze in dem kommunizierten Signal zu kreieren.

In dieser Dissertation habe ich zwei Studien zu zwei Typen von Gesichtsbewegungen mit einem Zeitumfang einzelner lexikaler Einheiten durchgeführt: Mundbilder und Ausdrücke des Ekels. In meiner ersten Studie habe ich die Behauptung, dass Mundbilder phonologische

Elemente sind, auf das Thema angewandt, wie gehörlose Menschen auf Deutsch lesen (Elliott, Braun, Kuhlmann, & Jacobs, 2012). In der zweiten Studie habe ich versucht zu bestimmen, ob Gesichtsausdrücke aus dem Bereich der Emotionen als phonologische Elemente gebraucht werden (Elliott & Jacobs, 2013; Elliott & Jacobs, eingereicht).

In der einschlägigen Literatur zu der Art und Weise, wie gehörlose Personen lesen, gibt es seit Langem eine Debatte darüber, ob sie beim Lesen auf Phonologie zugreifen und ob es eine Rolle in ihren Leseleistungen spielt. Dies ist von praktischer Bedeutung, da gehörlose Individuen im Durchschnitt nicht dasselbe Niveau von Lesefertigkeit erreichen wie hörende Gleichaltrige (Traxler, 2000). Im Vergleich mit der Literatur über das Lesen hörender Personen ist die Debatte bislang in Bezug auf zwei entscheidende Punkte theoretisch unspezifisch geblieben: 1) Die phonologischen Einheiten, die gehörlose Personen von der Lautsprache haben könnten, wurden noch nicht bestimmt, 2) es scheint keine expliziten kognitiven Modelle zu geben, die spezifizieren, wie Phonologie und andere Faktoren beim Lesen durch gehörlose Personen funktionieren. Im Rückgriff auf die Literatur über das Lesen hörender Personen (Braun, Hutzler, Ziegler, Dambacher, & Jacobs, 2009; Briesemeister et al., 2009; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Jacobs & Grainger, 1994) schlage ich vor, dass gehörlose Personen Repräsentationen von der sublexikalischen Struktur der Lautsprache haben, die auf Mundbildern basieren, und dass diese sublexikalischen Einheiten während des Lesens durch gehörlose Personen aktiviert werden. Ich bestimme sublexikalische Einheiten als 11 "Viseme" (Mundbilder) und ich bestimme ihre Rolle im Lesen durch Anpassung der Dual Route Cascaded Model of Reading (Coltheart et al., 2001) an mein Set von Visemen. Ich habe die indirekte Route des Modells bestimmt, indem ich ermittelt habe, ob gehörlose Personen den Effekt der "Pseudohomovisemität" während einer lexikalischen Entscheidungsaufgabe zeigen würden. Ich stellte einen Haupteffekt der Pseudohomovisemität fest, der suggeriert, dass wenigstens manche gehörlose Personen auf die sublexikalische Struktur während des Lesens einzelner Wörter automatisch zugreifen.

Nach meinem besten Wissen ist diese Studie die Erste, die die möglichen sublexikalischen Einheiten gehörloser Leser spezifiziert und ihre psychologische Gültigkeit in lexikalischen Entscheidungen durch Anwendung eines generellen Reaktionszeit Paradigmas der Worterkennungsliteratur für hörende Personen testet. Der erlangte Effekt der Pseudohomovisemität legt nahe, dass manche gehörlose Personen während des Lesens in der Tat auf sublexikale Einheiten - in Form von Visemen - automatisch zugreifen können. Nichtsdestoweniger muss die Arbeit zur Identifizierung der genauen Einheiten und zur Beurteilung individueller Unterschiede unter gehörlosen Lesern während ihrer Anwendung fortgesetzt werden. Wir definierten beispielsweise das Viseme-Set basierend auf visuellen und nicht taktilen Merkmalen. Es ist jedoch plausibel, dass gehörlose Personen mehr visemische Unterschiede aufweisen, als in diesem Bestand präsentiert, wenn taktile Merkmale berücksichtigt werden.

In meiner zweiten Studie habe ich mich bemüht, festzustellen, welche emotionsbezogene Ausdrücke von gehörlosen Sprechern der DGS als phonologische Einheiten benutzt werden. Es wurde beobachtet, dass Gebärden für Emotionskonzepte in American Sign Language (ASL) wie SAD (traurig) (Reilly, McIntire, & Bellugi, 1990) mit Gesichtsausdrücken produziert werden, die in ihrer Bedeutung mit den Emotionskonzepten übereinstimmen. In der

einschlägigen Literatur sind diese Art von Gesichtsausdrücken oft als phonologische Merkmale angesehen und nicht als Morpheme, da sie während einzelner lexikalischer Einheiten auftreten, aber im Gegensatz zu Gesichtsadverbialen werden sie nicht systematisch zur Modifizierung der Bedeutung von einer ganzen Klasse von Gebärden benutzt. Nichtsdestoweniger wurden diese Gesichtsausdrücke noch nicht eingehend untersucht, beispielsweise gibt es meines Wissens bislang noch keine Korpus-Studien, die ihren Zeitumfang bestätigen oder Daten zu ihrer Frequenz und Verteilung bereitstellen würden, was dazu führt, dass ihre linguistische Funktion - d.h. ob sie als phonologische Merkmale, Morpheme oder etwas anderes angesehen werden sollen - nicht gänzlich klar ist.

Ich fand Beleg dafür, dass ein emotionsbezogener Gesichtsausdruck durchgehend mit der Gebärde EKEL gebraucht wird und beobachtete, dass er einen Zeitumfang über die lexikalische Einheit hat. Durch den Gebrauch des Facial Action Coding System (Ekman et al. 2002b), habe ich ferner festgestellt, dass die genaue Art und Weise, wie ein Gesichtsausdruck produziert wird etwas eigentümlich ist, obwohl die gängigste Form Mundöffnen und Zungenprotrusion waren. Beim Versuch, die Funktion des Gesichtsausdrucks entweder phonologisch oder morphologisch zu erklären, stellt sich das Problem der offenkundigen Redundanz. Es ist dasselbe Problem, das beim Erklären davon, wie Mundbilder in DGS gebraucht werden, auftaucht. Phonologisch scheinen sie redundant zu sein, weil die manuelle Gebärdenkomponente meist ausreichend distinktiv ist, um zusätzliche Merkmale nicht zu erfordern. Morphologisch fügen emotionsbezogene Gesichtsausdrücke und Mundbilder dafür keinen neuen semantischen Inhalt zur Gebärde hinzu, sie scheinen den semantischen Inhalt der manuellen Komponente nur zu wiederholen. Dem Prinzip des geringsten Aufwandes folgend (Zipf, [1949] 2012), schlage ich vor, dass diese Redundanz nur scheinbar ist. Der Gebrauch von emotionsbezogenen Gesichtsausdrücken und Mundbildern muss für den Empfänger der Nachricht von Vorteil sein, sonst würde der Sender nicht die Anstrengung machen, zusätzliche Artikulatoren zu benutzen. Diese Hypothese kann in zukünftigen psycholinguistischen Studien überprüft werden.

Angesichts der gemeinsamen Merkmale von emotionsbezogenen Gesichtsausdrücken, Mundbildern und anderen Gesichtsbewegungen auf der lexikalischen Ebene - nämlich dass sie in der Regel einen Zeitumfang von einzelnen lexikalischen Elemente haben, dass sie einen bestimmten Grad vom semantischen Inhalt haben, und dass sie variierende Grade von Unabhängigkeit in Bezug auf die manuelle Komponente einer Gebärde aufweisen - betrachten wir sie als zugehörig zu einer Klasse von Phänomenen, die in Bezug auf folgende Aspekte variieren; (1) ihre Herkunft und (2) ihre Positionierung auf dem phonologisch-morphologischen Kontinuum. Ich schlage vor diese Klasse als eine zusätzliche Kommunikationsschicht erachte die wie ein paralleles Lexikon zur manuellen Komponente in der DGS funktioniert. Die Beziehung zwischen dieser Schicht und den manuellen lexikalischen Einheiten ist in bestimmten Weisen analog zur Beziehung zwischen Gesten und Wörtern, oder Intonationen und Wörtern. Insgesamt sprechen die Befinde dafür, dass Gehörlosen verwenden Gesichts-Bewegungen als phonologische Einheiten.

Contents

Notation Conventions

Signs from German Sign Language (Deutsche Gebärdensprache: DGS) are represented by using the German cognate written in caps with an English approximation in single quotation marks to the right:

EKEL 'disgust'

Signs from other signed languages are represented using the English cognate written in caps:

SAD

0. Introduction

0.1 Some linguistic history and my intended contribution to the field

Up until the 1960's most linguists assumed that true human languages are: necessarily acoustic in form, have an arbitrary link between form and meaning, and are reducible to a set of finite discrete meaningless units. Signed languages are transmitted visually, the link between form and meaning is more often than not iconically motivated, and it seemed that signs could not be decomposed into a finite set of meaningless units. Due to the assumption that signed languages are not true languages, many educators felt it should also not be used in deaf education and it was decided in the Second International Congress on Education of the Deaf in 1880 that signed languages should be prohibited in schools and that the deaf should be taught 'orally' (by using spoken language). During that time the 'oral' method was predominant in Germany, while the 'sign' method was predominant in France (Gallaudet, 1881). This shift towards oral education was very unfortunate for deaf students as it has been since shown that early acquisition of signed languages by deaf individuals actually facilitates learning of oral languages (Boudreault & Mayberry, 2006; Mayberry, 2007; Mayberry, Lock, & Kazmi, 2002).

An oralist position is still maintained in many parts of the world and in the Federal Republic of Germany for example, it was not until 2002 with the Behindertengleichstellungsgesetz (Disability Discrimination Act) that German Sign Language was legally recognized as a 'true' language, giving deaf signers the right to an interpreter should they need one in a court of law for instance. What this act essentially means however is that deaf signers have the right to use their language, but the state is not obliged to *educate* deaf people in their language (Pabsch, 2013). Education for deaf persons in Germany is provided primarily in German or in a mixed system of visually represented German called Lautsprachbegleitende Gebärden. This seems likely to change though, as the Deaf community has been petitioning the government for Signed Language teaching.

What happened in 1960 that caused a change in linguist's attitude to signed languages that eventually also caused the shift in German policy? One of the three assumptions mentioned above regarding what a true language is, was questioned through affirming one of the others: William Stokoe (1960) published a monograph in which he showed that American Sign Language signs can be decomposed into sub-lexical units, which led linguists to assert that Signed Languages show 'duality of patterning' i.e. are reducible to a finite set of discrete meaningless units (Sandler & Lillo-Martin, 2006, p. 113). The demonstration that signed and spoken languages could share some common abstract structural properties brought into question the relevance of what sensory form a structure is encoded in. The reason Stokoe's monograph had the impact it did, was probably also largely due to the general paradigm shift taking place in linguistics and psychology at the time, namely the 'cognitive revolution'.

The intended contribution of my dissertation is to present evidence from the use of facial movements as phonological elements that the other two assumptions mentioned above regarding the nature of language – arbitrariness and duality of patterning – are not more necessary to a language than acoustic transmission. I will show that the minimal elements of

German Signed Language are often not meaningless and that the forms are often iconically motivated. I am not the first person to question these assumptions. For example, Sarah Taub (2001) has gathered evidence and presented a theory to account for non-arbitrary forms in signed and spoken languages and a recent special issue in the *Journal of Language and Cognition* (de Boer, Sandler, & Kirby, 2012) presented papers re-examining the duality of patterning assumption. However investigations in these two areas are still in their infancy and it is in adding novel evidence to the pool and suggesting a functionalist theoretical framework in which to account for the data that I hope my contribution lies.

0.2 German Signers and Signed Languages

Signed languages are naturally acquired by children following a similar developmental sequence to that of acquisition of spoken languages, they arise spontaneously amongst communities of deaf persons, they are supported by the same neuro-anatomical substrates and they can be used to do all the things that spoken languages do such as to inform, entertain, command, comfort, etc. (Campbell, MacSweeney, & Waters, 2008; Emmorey, 2002). A common misperception is that signed language is universal. The opposite is in fact true. Every deaf community has developed its own sign language, and even within one country, there can be large dialectical differences between communities.

According to the Deutscher Gehörlosen-Bund (the German Deaf Association) there are 80,000 deaf people living in Germany and they comprise a cultural minority living within the larger hearing community. They are usually bilingual, that is, they can read and write and to some extent vocalize German, and some speak Deutsche Gebärdensprache (DGS) or use Lautsprachbegleitende Gebärden (Manually Coded German). They are a very heterogeneous group with regards to the age at which they acquired signed language, the type of exposure they have to signed language and German, and the contexts in which they use them.

Deaf identity is often an emotionally and politically charged issue for deaf individuals. For example from my experience deaf participants preferred that questionnaire's should allow them the opportunity to mark both whether they are audiologically deaf and whether they regard themselves as culturally Deaf (conventionally written with a capital D). As far as I understand, the point in distinguishing between deafness as a pathology and Deafness as a culture is to raise awareness that besides the factor of auditory deprivation there are many broader social, cultural and cognitive factors that play a role in a deaf individual's development (Corina & Singleton, 2009) and that some deaf individuals do not necessarily regard their deafness as a handicap.

0.3 What is language?

I maintain the following working assumptions regarding the nature of language; it is a cognitive system whose primary function is for communication. It allows humans to combine meanings with perceptual-motor forms and to further combine these units into complex semiotic structures.

'Functionalist' is a term usually applied to theories of language which assume that language is a system for communication, and that language is shaped by two main principles: the desire to

exert minimal effort and the desire to create maximally distinct perceptual cues. It has its historical origins in the works of the Prague School but I have drawn mainly from the more recent developments and formalizations of these basic principles in the works of Yishai Tobin (1997) and Paul Boersma (1998) as well as my own developments based on the sign language evidence I have acquired. In what follows I will offer my justifications for my working assumptions.

0.3.1 Language is a Cognitive System

My first working assumption is that language is a cognitive system. Language is a psychological phenomenon in the sense that it is produced by the normally functioning brain. Within the set of psychological phenomenon, I further classify language as 'cognitive' since language appears to involve complex operations on sensory information. By 'system' I mean a collection of units that interact with each other and as a result of their interaction create phenomena that could not be created by any one unit on its own. I refer to language as a 'cognitive system' since it appears that the use of language requires that several cognitive units (which in themselves are probably systems), such as memory, theory of mind, emotion, motor planning and motor execution function together.

I regard the fact that damage to certain parts of the brain can cause impairments in language use as evidence that the brain is the seat of language. I also regard the fact that damage to different parts of the brain result in different kinds of language impairments as evidence that language is a system in the sense that it is composed of a number of units that appear to be distributed in the brain and that function together so that damage to different units results in qualitatively different deficits manifest in the entire system. For example, damage to left Broca's area and some of the surrounding tissue (BA 44, 45, parts of 6, 8, 9, 10 and 46) results in effortful and slow speech with many pauses, as well as incorrect usage of conjunctions, prepositions and inflectional affixes while damage to the left posterior auditory association cortex (BA 22, but also 37,39,40) results in fluent speech with deficits in phoneme assembly, naming, and intelligibility of content as well as deficits in comprehension of speech (Damasio, 1992). Neurolinguistic research using PET and fMRI has also made it possible to observe correlations between brain areas and particular linguistic tasks in healthy experimental participants (Price, 2012). However, questions regarding the systemic nature of language, i.e. what exactly do the implicated brain regions do and how do the regions work together – still remain largely unanswered.

0.3.2 The Function of Language is Communication

My second working assumption is that the primary function of this system is for humans to communicate. By communicate, I do not mean merely to inform, I mean to intentionally cause a human to have a meaning in their mind in the broadest sense. My broad sense of meaning includes how things look, feel, sound, taste, to how things work, why things work, feelings and understanding of social relationships. The goals we have for communicating vary, for instance often we cause others to have a meaning in their mind in order to cause them to do something, while other times we communicate in order to make them feel something, and yet other times in order to make them understand something. The point I wish to make clear

however, is that despite the different goals of these communicative acts they all have in common that they are cases of intentionally causing a human to have a meaning in their mind. I provide three very different examples of what I call communicative goals to illustrate this.

Perhaps one of the most common communicative goals is 'phatic communion' (Malinowski, [1923] 1989). In phatic communion humans use language in order to establish, confirm or alter the nature of their relationships with each other. Bronislaw Malinowski who coined the term 'phatic communion' provides the following analysis of greetings and small talk:

> "The modern English expression, 'Nice day to-day' or the Melanesian phrase, 'Whence comest thou?' are needed to get over the strange and unpleasant tension which men feel when facing each other in silence.
>
> After the first formula, there comes a flow of language, purposeless expressions of preference or aversion, accounts of irrelevant happenings, comments on what is perfectly obvious. Such gossip, as found in primitive societies, differs only a little from our own." (p. 314)

In such exchanges there seem to be two communicative goals. The primary communicative goal is to cause a human to know what the nature of their relationship to oneself is. Formulas such as 'How are you?' which are syntactically anomalous and appear un-decomposable seem to only carry this primary meaning. Their meaning would be something like 'I would like to start a communicative exchange with you'. However the 'purposeless expressions of preference' in the Malinowski example above appear to have a dual communicative function. The primary function is to cause a human to have the meaning of approximately 'I am willing to share personal information with you and invite you to do the same' while the secondary communicative function would be to convey the 'literal' meaning carried by the words i.e. to inform the interlocutor about one's preferences. Evidence for the dual communicative goals of phatic communion is found in the form of selective impairments in comprehending the pragmatics of language on the part of persons displaying degrees of autism (Surian, Baron-Cohen, & Van der Lely, 1996).

Another communicative goal is to cause a human to experience aesthetic feelings (Bohrn, Altmann, Lubrich, Menninghaus, & Jacobs, 2012). Malinowski ([1923] 1989) describes this function well in stating that: "In poetic and literary production, language is made to embody human feelings and passions, to render in a subtle and convincing manner certain inner states and processes of mind." (p. 316). Artistic uses of language also seem to be comprised of primary and secondary communicative goals. The primary communicative goal is to cause a human to experience some kind of emotional state which can be very complex and unique if one considers for example the term 'Kafkaesque'. This term arose to refer to the feelings of false hope then despair experienced when confronted by arbitrary and circular rules which keep one perpetually moving but never arriving, evoked in many readers by the works of Franz Kafka. The secondary communicative goal is to inform about events taking place in a fictional space. Evidence for the dual communicative goals of artistic language is found in the form of selective impairments in comprehending metaphor and irony on the part of persons

displaying degrees of autism (Happe, 1993). A neurocognitive working model that reflects the dual nature of literary language reading is proposed in (Schrott & Jacobs, 2011).

A third communicative goal is to regulate one's own emotions and thoughts which means that one can cause oneself to have meanings in one's mind. An example of this is the use of swear words. Stephens and colleagues (Stephens, Atkins, & Kingston, 2009; Stephens & Umland, 2011) found that participants repeating a swear word were able to keep their hand in a bucket of ice water on average 40 seconds longer, had increased heart rate, and reported reduced perceived pain than participants repeating a non-swear word. The authors propose that by repeating a swear word the participants provoked an emotional response of aggression in themselves which could lead to increased pain tolerance. In the case of swear words too, there is a split between primary and secondary meanings. The primary meaning is something like 'I feel aggressive now' and the secondary one is often 'feces' or 'genitals'. Further evidence of the use of language to cause effects on oneself are reported for example in (Prehn et al., 2011) in which it was found that subjective emotional experience and brain activation patterns towards pictures varied depending on whether participants verbalized facts, acknowledged their emotions, or denied their emotions.

Communication – the causing of a human to have a meaning in their mind – seems often to be composed of at least two levels of meaning. I have called these two levels 'primary' and 'secondary'; however these terms can roughly correspond to what other authors describe as 'pragmatic and figurative senses' and 'literal sense' respectively. Evidence for these two levels of meaning is found in individuals displaying degrees of autism. They are often selectively impaired in understanding the primary (pragmatic and figurative) senses of language but not impaired in understanding the secondary (literal) sense of language.

0.3.3 Linguistic Forms are Sensorimotor Entities

My third working assumption is that linguistic forms are sensorimotor in nature. By this I mean that what are usually called 'phonemes' in the literature are mental categories that contain abstracted information about muscle movements and acoustic, visual and proprioceptive perceptual information. If one is deaf or blind naturally some of the perceptual information will be missing. I use the term 'abstraction' in the first two senses described in Barsalou (2005): (1) categorical knowledge and (2) the behavioral ability to generalize across instances. Evidence that phonemes are abstractions lies in the fact that variant sensorimotor productions, for example the production of /p/ in the English words 'pen' and 'spend' which differ acoustically in aspiration, are however identified as the 'same' sound by native speakers of English (Tobin, 1997, p. 22).

Evidence that phonemes activate at least both visual and acoustic representations is shown by the McGurk effect (McGurk & Macdonald, 1976) in which the visual component of a phoneme can cause one to report hearing a sound other than was actually spoken: when moving the lips as if to say /ga/ but the auditory information of the syllable /ba/ is heard, subjects report hearing /da/. Phonemes with salient visual features are also preferred in word initial position where it is efficient to place more perceptual cues (Tobin, 1997, p. 44). The visual features of phonemes can also be used by deaf individuals to form their phonological

representations of spoken languages (Elliott, Braun, Kuhlmann, & Jacobs, 2012). Evidence that motor representations are evoked in speech perception is harder to find because it is experimentally harder to independently manipulate movements and their visual or acoustic results than it is to independently manipulate the visual and acoustic material. However, when a person is instructed to respond with /pa/ whenever they hear a syllable, production is facilitated when preceded by acoustic presentation of the identical syllable than when it is preceded by /ta/ or /ka/ (Fowler, Brown, Sabadini, & Welhing, 2003). Fowler et al. interpret this facilitation effect as arising from the possibility that perception of the acoustically presented syllables must also activate motor representations, which would than prime the motor action required of the subject.

Boersma (1998) claims that in speech production the motor representations of phonemes are the proximal targets, while the perceptual specifications are the distal targets. By this he means that in speaking the immediate considerations driving the movement of the articulators are previously learned locations, constriction degree, and air pressure in the vocal tract which are monitored by the proprioceptive system, while information about the target acoustic results only comes in later from the much slower auditory feedback loop. Evidence that the motor and perceptual features are to some degree independent is found in the fact that there is no one-to-one mapping relationship between articulatory movements and perceptual results. For example the perceptual feature 'nasal' is usually associated with the articulatory feature 'lowered velum', but velum lowering does not always guarantee a nasal sound quality. For example the same amount of velum lowering that would result in the perception of nasality in high vowels is not sufficient for nasality in low vowels (Boersma, 1998, p. 19).

Evidence that the motor specifications are the proximal targets rather than the acoustic ones is found in the following experiment:

> "If you ask someone to pronounce a central (e.g. Dutch) [a] with her teeth
> clenched, she will make compensating tongue and lip movements; however,
> because [a] is not specified for horizontal lip spreading, she will not draw the
> corners of her mouth apart, though this would yield a much more [a]-like sound;
> she will only learn this trick after some practice, using auditory feedback."
> (Boersma, 1998, p.14)

What this experiment is thought to demonstrate is that some articulatory features can be compensated for almost immediately through proprioceptive feedback when the jaw is perturbed, but some features can only be compensated for later through learning using acoustic feedback. The difference between the features that can immediately be compensated for and the ones that require some kind of learning lies in whether a particular phoneme in a particular language is specified for that movement or not. In the example above the speaker has associated particular specifications for lip and tongue movements with the production of [a] and can immediately compensate for jaw perturbations that effect these particular stored features. However, information about lip spreading is not specified for the production of [a] and so the speaker in the above example can not immediately compensate for this. She can only make full compensation after comparing the actual acoustic result with the desired

acoustic result. Another way to state this is to say that the motor representations forming the proximal targets of production are under-specified.

Figure 0.1 below is a representation of Boersma's (1998) model of integration of phonology into speech production. The model makes a principled distinction between motor and perceptual representations of linguistic forms. Even though Boersma developed this model to account for spoken language data, such a model is general enough in principle to account for the phonology of signed languages. By replacing the acoustic features with visual ones and the oral tract with the relevant muscles used by signers, one has a model of signed language production as shown in figure 0.2.

Figure 0.1 Paul Boersma's (1998) model of integration of phonology into speech production
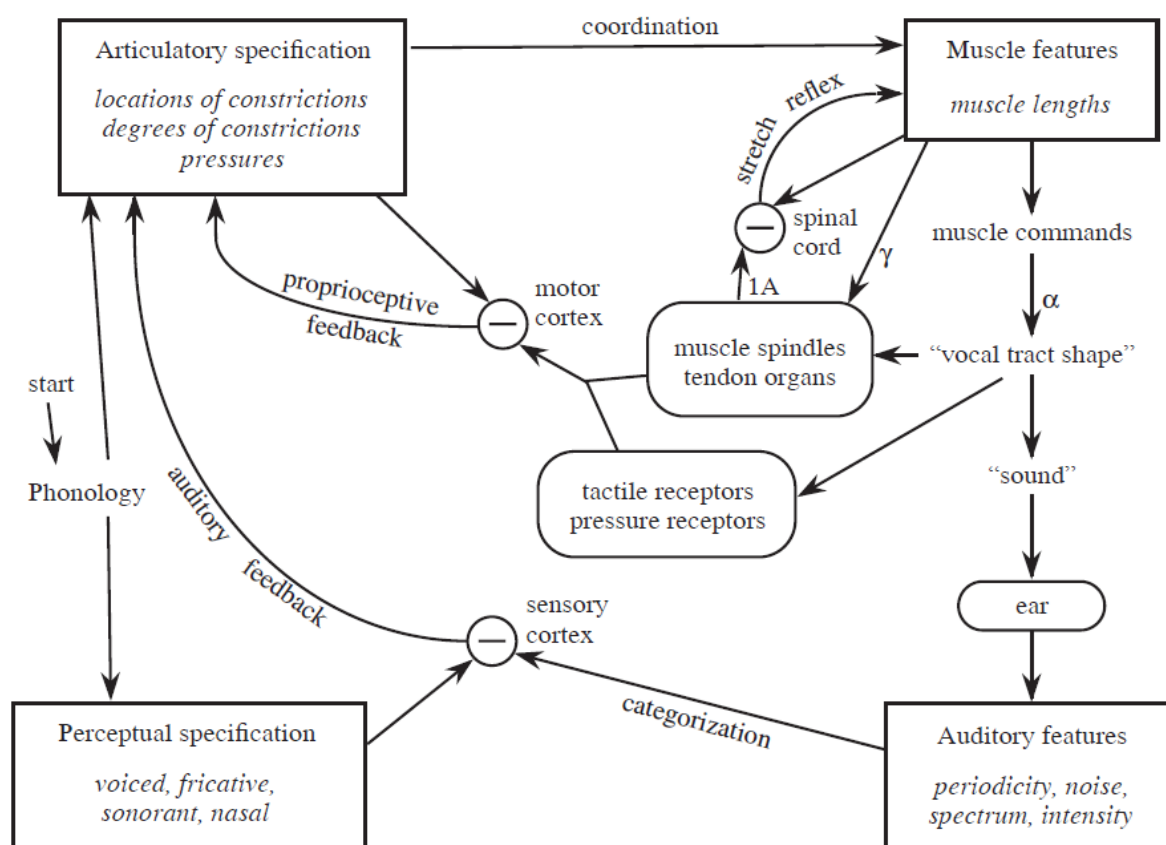
Fig. 1.1   Integration of phonology into speech production.
Rectangles = representations. Rounded rectangles = sensors.
Encircled minus signs = comparison centres. Arrows = causation.
α, γ, 1A = nerve fibers.

Figure 0.2 A model of signed language production based on Boersma (1998)
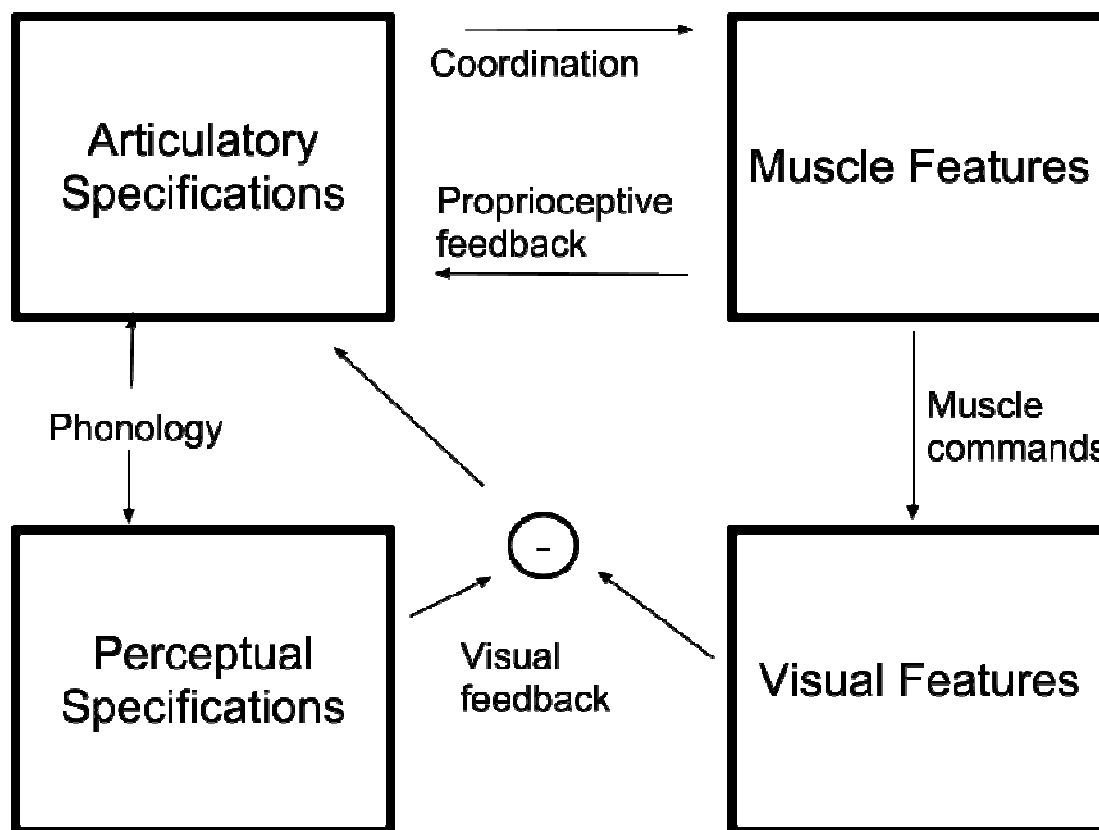
From the assumption that linguistic forms are sensorimotor entities it follows that at least some parts of language can be explained by reference to the general constraints on the human motor system and the human perceptual system. These constraints should apply equally to signed and spoken languages. The differences between the languages as far as these constraints are concerned will lie in the fact that the larger muscles of the arms which are the primary articulators in signed languages, and the smaller oral muscles which are the primary articulators of spoken languages may be affected differently by the constraints on motor action. Furthermore, signers might also rely more on proprioceptive feedback than on visual feedback, since many of the articulatory gestures signers make, particularly those of the face, cannot be seen by the signer herself.

0.3.4 Optimal Rate of Meaning Transfer

My fourth working assumption is that language, at least at its secondary (literal) level of communication, has an optimal rate of meaning transfer. Above I showed that there is evidence that when using language to communicate there are usually primary (pragmatic/figurative senses) and secondary (literal) levels of meaning involved. In a study comparing the rate of American Sign Language signing and American English speech, it was found that even though speech rate (measured in words per second) was twice as fast as signing rate (measured in signs per second) both languages have a constant proposition rate,

as gauged from the secondary level of meaning. The hands move slower than the mouth, and therefore the amount of signs a signer makes per second (2.5 signs/sec for American Sign Language) is less than speech rate (4.5 words/sec for American English). However, the amount of propositions made in both languages was the same (0,6 propositions/sec). This is possible partially because signers can use their face and their hands simultaneously giving them the ability to essentially say two words at the same time and also because of the efficient use of space to designate relations (Klima & Bellugi, 1988). For example the verb HELFEN 'to help' in German Sign Language (Figure 0.3) can mean 'I help you' or 'you help me' depending only on the start and ending points of the hands. This means that one sign can convey the same meaning as three English words.

Figure 0.3 HELFEN 'to help'

    a. 'I help you'
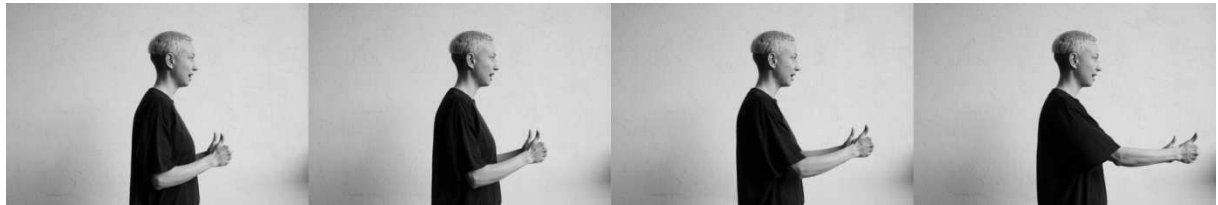
    b. 'You help me'
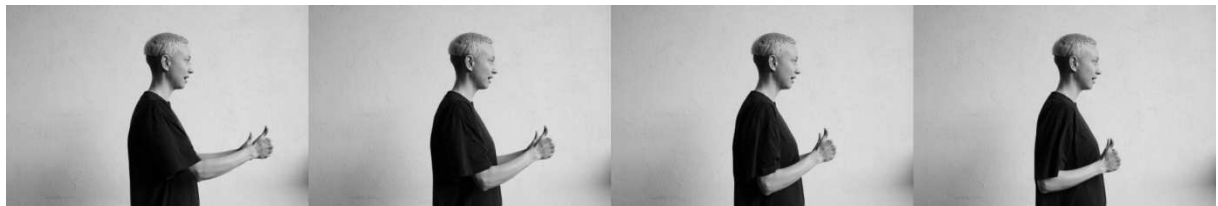
Further evidence for an optimal rate of meaning transfer from seven different spoken languages can be found in the work of Pellegrino et al., (2011). They found that in their corpus of spoken language material that the more semantically dense a syllable is in a particular language, the slower the syllable rate was. Semantic density was operationalized in the following manner: A corpus composed of 20 texts was used. Each text was made of five semantically related sentences that comprised a narration or query. Each text was freely translated from English into seven languages; therefore it is assumed that the texts have equivalent semantic content. Semantic density was then calculated using an eighth language as a reference for normalizing as presented in the formula in figure 0.4 below in which; ID = Information density, I=Information, K= Text, L=Language, σ= total syllables in text, VI = reference language:

Figure 0.4 Pellegrino et al.'s, (2011) formula for semantic density of a syllable

$$ID_L^k = \frac{I_L^k}{I_{VI}^k} = \frac{S_k}{\sigma_k(L)} \times \frac{\sigma_k(VI)}{S_k} = \frac{\sigma_k(VI)}{\sigma_k(L)}$$

This finding fits in well with the signing data in which it is shown that signs, which are denser than spoken language words, are produced at a slower rate than the less dense words of American English. It would seem that signs have no choice but to be semantically denser than words because the speeding up of articulation is physically not an option. This data, to my mind, strongly suggests that there is an optimal amount of meaning that humans can process per time unit. However, as I keep stressing, this observation is valid for the secondary (literal) sense of language. I am not aware of studies that attempted to measure the semantic density of the primary (pragmatic or literary) senses of language.

0.3.5 Horizontal and Vertical Structure in Language

In language there is both sequential 'horizontal' structure and 'vertical' simultaneous structure. Horizontal and vertical structure can be seen at different levels of language organization including the phonological and lexical levels. For example, in spoken languages it is recognized that what were usually called phonemes are made of phonological features (Sandler & Lillo-Martin, 2006, p. 122). For example the phoneme /b/ is composed of a bilabial feature and a voicing feature. These features are produced simultaneously, but they have some degree of independence in that one can last longer than the other and spread over to the next sequential element. Similarly in signed languages, articulatory features such as handshape, movement, and location are produced simultaneously, but the handshape feature is independent of the others in that it can be maintained over a long sequence of alternating movements and locations.

At the lexical level words/signs display horizontal structure in that they can be combined with each other to create sentences. Words and signs also show vertical structure in that they can be simultaneously combined with intonational units, gestures, or facial expressions which can alter their meaning. Consider for example saying the word 'yes' with a constant tone and 'yes' with a rising tone. The second 'yes' would usually be interpreted as a question or an indication of uncertainty rather than affirmation. Similarly, in signed languages, producing a sign with raised eyebrows can signify a question and neutral eyebrows a statement (Dachkovsky & Sandler, 2009).

That co-speech gestures are a part of the vertical structure of language has only recently gained broad acceptance largely through the work of David McNeill. McNeill (1992) showed that co-speech gestures occur at a rate of about one gesture per clause. They are timed to the onset of particular lexical items. They add complementary information to that encoded in the lexical item: for example if I say 'he climbed up the pipe' my hands may make a gesture showing the manner in which 'he' climbed. The information on manner complements the information given by the verb 'climb'. The preparation phase (hands moving into position) of a gesture anticipates speech, and then synchronizes with it during the stroke (the execution of the gesture). The stroke is timed to end at or before, but not after, the peak syllable. Furthermore, studies in production and perception have shown that speech and gesture are hard to separate: delayed auditory feedback and clinical stuttering disrupt speech timing, but do not disrupt speech-gesture synchrony. After a delay in speech perception, listener-viewers cannot tell whether a particular piece of information was conveyed in the verbal content or in

the gestural content (McNeill & Duncan, 2000). Signers also make co-speech gestures, but they use their face for the gestures and their hands for the lexical output (Sandler, 2009).

Signers make greater use of vertical structure by combining facial and manual movements than speakers of spoken languages do. They are motivated to make greater use of vertical structure presumably because the ability to create fast sequences of phonological features (as can be done with the smaller oral muscles) is not available to them. Signers can use the face to create a parallel lexicon to the one produced by the hands and therefore say two words at the same time. For example in American Sign Language the adverbial CARELESSLY - which is made by tilting the head back and sticking the tongue out slightly - can simultaneously combine with manual verbs such as DRIVE, WRITE etc. to create a meaning equivalent to 'drive carelessly'.

0.3.6 Duality of Patterning

My sixth working assumption is that duality of patterning is a statistical tendency in languages rather than a defining feature. Duality of patterning, henceforth DoP, refers to the notion that languages can be reduced to meaningless elements such as the sounds /t/ /a/ /k/ that can combine in different ways to form meaningful units such as 'tack' 'act' and 'cat' (Hockett, 1960). The patterning is called dual because it is proposed that two different kinds of rules govern the combination of meaningless elements into meaningful units and the combination of meaningful elements with each other (Ladd, 2012). Hockett (1960) proposed that DoP is a design feature of human languages and most linguists still maintain this, at least in so far as that every language must be reducible to a finite set of discrete meaningless elements (de Boer, Sandler, & Kirby, 2012). However, I do not assume that DoP is a necessary feature of language. Like Blevins (2012), I view DoP as a statistical tendency rather than an absolute universal. This means that even though in most languages the minimal units are usually meaningless, there may be languages which do not have this property at all, or that within a language some of the minimal units may be meaningful all of the time, or some of the minimal units may be meaningful in some contexts.

What are the minimal units of language? The phonological feature is usually regarded as the smallest unit of analysis in language, but since not all phonological studies make the clear distinction that Boersma makes between articulatory and perceptual features, there is some variance in the literature in how they are defined and consequently how many of them there are. Based on articulatory specifications one can define a distinctive feature as a minimal articulatory act. An example would be palatalization, in which one raises the back of the tongue towards the palate resulting in a /j/-like sound when air is simultaneously run through the oral cavity. Even though this movement can be further decomposed into three phases: raising towards the palate, holding at the palate, and retraction, all of these sub-movements are motivated by the same proximal goal – to bring the tongue temporarily to the palate. The distal goal is to create a /j/-like sound. In signed languages the minimal units can also be described in terms of minimal articulatory acts, but the articulators being used would be the hands, the fingers, the face or even shifts in the position of the torso.

Blevins (2012) cites evidence from many unrelated languages that contrary to the claim that DoP is universal, the minimal units of a language are not always meaningless. In Isthmus Mixe (a Mexican language) palatalization is consistently associated with the meaning 3rd person singular possessive when on the stem initial consonant. For example /pam/ = illness, /p^{j}am/= her illness. In Japanese mimetics, palatalization is associated with the meaning 'childishness/uncontrolledness' which creates the following contrast: poko-poko = up and down movement, p^{j}oko-p^{j}oko = impudently jumping around. In signed languages too, minimal articulatory acts, such as the bending of the first knuckles on the hand (the metacarpophalangeal joints) to create the so-called 'B-bent handshape' in Israeli Sign Language is associated with the meaning 'delimitation' (Fuks & Tobin, 2008). In signed languages association of features with meanings is very common and the meanings that are attached to the minimal articulatory acts are usually iconically motivated. For example the B-bent handshape is an image of a limiting barrier. Another example of iconically motivated phonological features is the association of the head location with mental processes such as the signs IDEE 'idea', PHILOSPHIE 'philosophy', TRAUM 'dream', KENNEN 'know' in German Sign Language.

Figure 0.5 The DGS signs IDEE, PHILOSPHIE, TRAUM, KENNEN all located at the head

Despite the evidence that minimal units of language are not always meaningless the assumption that DoP is a defining feature of language is so entrenched that most phonological theories reject the idea that meaning and iconicity could have any role in phonological processes. I quote for example Sandler and Lillo-Martin (Sandler & Lillo-Martin, 2006) on the issue of handshape specifications in signed languages:

> "This idea [that iconicity plays a significant role in handshape specification] […] is beyond – even incompatible with – phonology as we know it […]." (p. 169)

However, the functional model of speech production I adopt from Boersma, in which perceptual and articulatory specifications are separately represented and function as proximal and distal targets in the production process, can accommodate the impact of iconicity on phonology without any alterations. One needs only to recognize that the distal perceptual targets can be iconically motivated.

If features and segments can be meaningful in principle and in many cases are meaningful in practice, why is the statistical tendency towards them being meaningless? Blevins explains that as far as features are concerned, for spoken languages most of them cannot be realized in isolation. For example nasalization which in terms of minimal movements requires velic aperture and nasal airflow, requires the presence of other features such as voicing to carry it. Since most features are not independent, they cannot in principle be freely distributed in a

language. This means that features produced merely to facilitate the production of another feature would be confused with cases in which they are produced to convey meaning. Not only can they not freely combine, there also seems to be too few of them for creating a useful human vocabulary. There is argument as to exactly how many features exist, but the proposals range from 8-40. As far as spoken languages are concerned then, having a set of meaningless units which only have the function of creating perceptual distinctions is an efficient way to create large and potentially infinite vocabularies.

The case is slightly different for sign languages. The hands and face provide a much larger range of possible features that can be independently articulated. For example the Hamburg Notation System specifies 142 different possible handshape features alone (Prillwitz, Leven, Zienert, Hanke, & Henning, 1989). In combination with movement and location features it is conceivable that a signed language in which there are no meaningless elements can still be productive, and in fact, it is claimed that such a signed language exists: Al Sayyid Bedouin Sign Language (Sandler, Aronoff, Meir, & Padden, 2011). However, other signed languages such as American Sign Language and German Sign Language also fail to display DoP when signers use classifier constructions (Sandler & Lillo-Martin, 2006, p. 16).

Classifier constructions consist of using a specific handshape, for example the B-handshape shown in figure 0.5, to denote an entire class of nouns and then moving the handshape in an iconic manner as further described below.

Figure 0.6 B-handshape

The B-handshape when oriented palm down can be used in German Sign Language and in American Sign Language to represent flat rectangular things such as cars, when oriented with the blade down it can represent thin things like bicycles or motorbikes. This hand shape can be combined with a complex movement, such as swerving from side to side, going sharply up then going sharply down, that conveys the predicate component of the construction. In English the equivalent meaning would be something like: "The car was swerving on the road than it went steeply uphill and steeply downhill". These constructions are phonologically anomalous because the usual constraints on manual signed forms such as symmetry of movement are violated. In signing a sign the two hands either make symmetrical movements, or the non-dominant hand stays still while the dominant hand makes a movement. There are no signs in which the two hands move independently. However in classifier constructions both hands can take on independent roles. In the car example, the non-dominant hand can take on the role of a motorbike that is overtaking the first car in the narration.

Figure 0.7 A comparison of lexical signs and classifier constructions

a. **The DGS sign DECEMBER composed of symmetrical movement**

b. **A classifier construction denoting a bike overtaking a car using asymmetric movement**
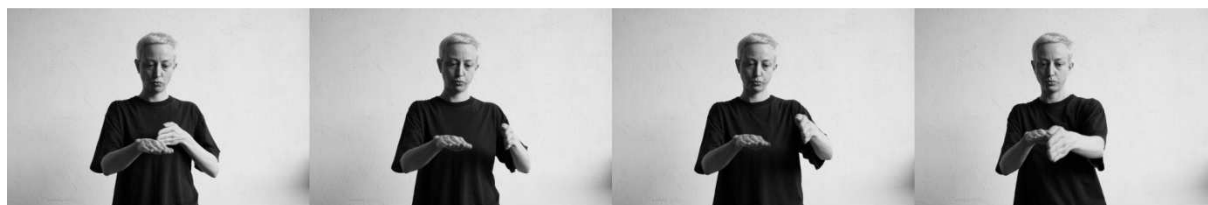
Figure 0.6 above illustrates the usual constraints on the function of the non-dominant hand in lexical signs from German Sign Language, compared to the independent role the non-dominant hand can take on in classifier constructions. Importantly regarding the issue of DoP, in classifier constructions the handshape feature is clearly meaningful, while in the lexical signs the handshape feature is not always associated with a meaning.

0.3.7 Iconicity

I assume that the forms of language are often motivated by their meaning based on an abundance of evidence from signed and spoken languages gathered for example in the work of Sarah Taub (2001). The term for form-meaning resemblance is iconicity. In signed languages forms overwhelmingly resemble their meanings visually. For example action verbs resemble the actual action one would do to perform the action in real life, such as 'hammering action' meaning 'to hammer'. Forms can be traced in the air, or depicted with parts of the body, such as making 'bunny ears' with the hands placed on the head to mean 'rabbit' and spatial relations between objects can be represented by spatial relations between locations pointed to. Sound-meaning resemblances exist in spoken languages, for example ring, ding, buzz, bang, etc.; however they are scarcer than iconic forms in signed languages because most things important to humans do not seem to have a characteristic sound to motivate their form. Taub (2001) concludes, based on the existence of visual, acoustic and other types of iconicity across languages, that forms 'try' to be as related to their meanings as possible.

How are iconic forms derived? Taub (2001) developed the analogue building model to answer this question. The model specifies three steps through which an iconic form is built. The first step is called image selection. In image selection a rich concept such as the chime of a bell which has specifications for timbre, pitch, sound envelope etc., is represented by a less rich prototypical image for a bell chime, graphically represented in figure 0.8 below. The second step is called schematization. In schematization the prototypical bell chime is further abstracted so that its features can match the features available in the language, in English for

example this would the syllabic features of onset, nucleus, and coda. The schematized bell chime features would thus be: abrupt onset, loud midsection, and gradual fade. The third phase is called encoding: the schematic features are encoded by mapping the following features onto English segments: abrupt onset - /d/, loud midsection - /i/, and gradual fade /ng/. These segments make up the distal perceptual targets in the phonological model I adopt from Boersma.

Figure 0.8 The analogue building process of the iconic word 'ding' from Taub (2001)
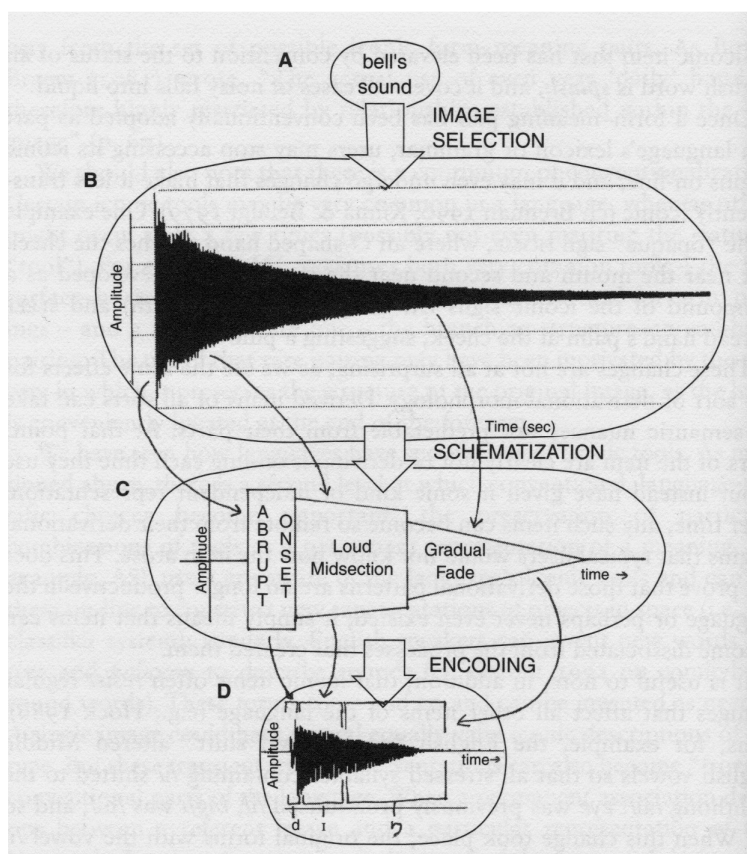
An example of the analogue building process in signed languages is presented with the sign TREE. In image selection a rich concept such 'tree' containing information regarding size, shape, texture, and smell, amongst others, is represented by a prototypical image of tree containing less information. For example it may be specified for the trunk, earth, branches and leaves. In the second step, schematization, this image is further abstracted so that the remaining features can fit into the existing categories of the language. In the tree example this means that long tall structure, perpendicular to a flat surface, with some branching structure above is preserved. In the final encoding stage the schematic features are mapped onto the articulators of the language. Long tall structure is mapped onto the arm of the dominant hand, flat surface is mapped onto the arm of the non-dominant hand, and branching structure is mapped on to the palm and fingers of the dominant hand.

Figure 0.9 The analogue building process of the iconic sign 'TREE' from Taub (2001)
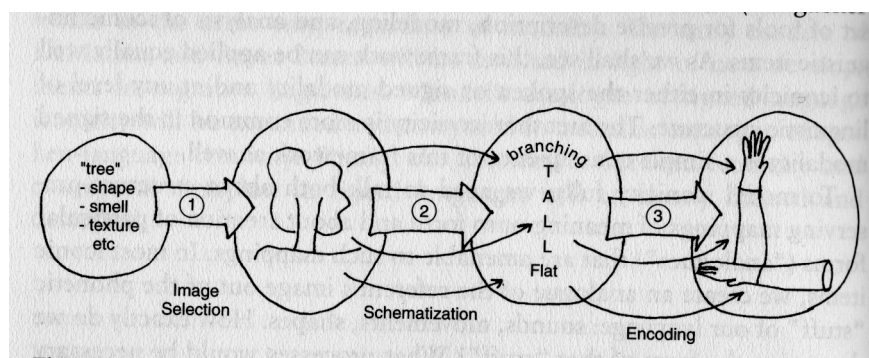
0.3.8 Definition of Phonological

Above I defined phonemes as mental categories that contain abstracted information about muscle movements and perceptual information. However, this definition lacks one important component. It is not enough that phonemes be defined as absolutely perceivable units; they also need to be defined as units that are distinguishable from one another. Humans do not attend to all the perceptual information produced while speaking and signing, but only to the information that makes meaningful distinctions, and this varies from language to language. For example in English if I pronounce /pen/ with aspiration [p^{h}en] or without [pen] a native English listener would still infer that I mean 'an implement to write with using ink'. However for a speaker of Hindi, in which aspiration is a distinctive feature, the two pronunciations would not be regarded as referring to the same word.

The units that make the meaningful contrasts in languages are not necessarily feature sized. Blevins (2012) cites evidence from Semitic languages for the existence of non-feature sized phonological units. Many Semitic languages use syllable templates that are only specified for the features usually called vowel and consonant to create minimal contrasts such as CVCVC vs. CVCCVC.

Based on the theoretical assumptions I presented above, I define the term 'phonological' as: having the function of differentiating linguistic elements from one another by creating perceptually salient cues. These cues can come in various shapes and sizes. Even though phonological elements have the function of creating perceptual distinctions they can also sometimes simultaneously have a semantic function.

0.4 Phonological Facial Movements

In this section I will describe the facial movements used in signed languages that usually have temporal scope over a single sign, i.e. they begin with onset of the movement of the hands and end with offset of the movement of the hands for one sign. These types of facial movements are usually divided into two groups: mouthings and mouth gestures (Boyes Braem & Sutton-Spence, 2001). Mouthings are movements of the lips that are derived from spoken language words. For example a signer could make the sign WURM 'worm' with her hand and simultaneously move her lips as if to say 'wurm'. The term mouth gesture is used for movements of the lips that are not derived from spoken languages however these type of lip movements are sometimes also made together with other facial muscle movements such as

brow furrowing and nose wrinkling (Sutton-Spence & Day, 2001, p. 79) and so the term face gesture, or simply facial movements as used in my dissertation title, would be more accurate. Mouth gestures include: adverbials such as the American Sign Language head tilt with tongue protrusion that means CARELESSLY; enacting gestures such as a 'kiss' mouth with the sign KISS in British Sign Language, or the puffing out of the cheeks to form an adjective meaning BIG or FAT in German Sign Language. All these types of facial movements seem to have some semantic content. However there are also facial movements with scope over single signs that appear to have no semantic content, they seem to only echo the movement of the hands. That is, if the hands make an opening movement, so does the mouth (Woll, 2001).

There is controversy over how these facial movements should be linguistically classified. Since most of these facial movements have semantic content, most researchers do not classify them as phonological since most researchers assume duality of patterning is a linguistic universal, i.e., that phonemes are necessarily meaningless elements. However, many facial movements despite having semantic content do not appear to be like typical morphemes either, since in many cases the semantic information they carry appears to be identical to the semantic information conveyed by the hands and therefore appears redundant. An example of this is, moving the lips as if to pronounce 'wurm' while making the sign for WURM with the hands. The differences between the types of facial movements has motivated some researchers to regard mouthings and mouth gestures as distinct phenomena (e.g. Ebbinghaus & Hessmann, 2001), however based on my analysis of the differences and similarities between these movements, and following my working assumptions regarding language above, I propose that the various facial movements with scope over single signs are the same phenomenon, and that the primary function of these facial movements is phonological, i.e. differentiating linguistic elements from one another by creating perceptually salient cues.

The similarity between these facial movements is their temporal scope. Unlike emotion related facial expressions, and prosodic facial movements made by signers while signing, these facial movements all have scope only over a single sign. To my understanding this strongly suggests that the motivation for this facial movement is to make single signs perceptually distinct from one another. These facial movements differ on two dimensions; origin and the extent to which they add semantic content. These facial movements originate either from the ambient spoken language, or as iconic enactments (kiss mouth to mean 'kiss') or iconic representations (puffed cheeks to mean 'big'), or as imitations of hand movements (opening of mouth together with opening of hands). Some of these facial movements add new semantic content ('careless' face with the hands signing WRITE which means 'to write carelessly'), some have the same semantic content as the hands (mouthing of 'wurm' with the manual component WURM), while others appear to have no semantic content. In my second study I further develop this argument and provide evidence for it (Elliott & Jacobs, submitted).

0.5 The Reality of Phonology

Despite the fact that it is uncontroversial that any scientific explanation of language must assume that language stems from the brain, linguistics is often practiced as if behavioral,

cognitive and neurocognitive findings are irrelevant to linguistic theory. Poeppel and Embick (2005) state this well:

> "We take it that the central question of neurolinguistic research is the question of how the grammar of human language is computed in the human brain. Our revised research program diverges from a familiar assumption in linguistic theory, which often proceeds as if experimental evidence -- whether from neuroscience or psycholinguistics -- is in principle irrelevant to theories of how language works. This assumption, which is often tacit in linguistic theory, is made manifest in the idea that there might be notions of 'psychological' or 'neurological' reality that are distinct from the reality that linguistic theory addresses. […] There is no need for terms like 'psychologically real' or 'neurologically real.' These terms, because they are qualified, imply that there is some other type of reality to linguistic computations beyond being computed in the brain. If a linguistic analysis is correct -- i.e. identifies something real -- it identifies computations/representations that are computed in the minds/brains of speakers. How these computations are implemented at different levels of biological abstraction is the primary analytical question for neurolinguistics. […] Just as the research program of neurolinguistics must be informed by linguistic theory, linguistic theory cannot proceed in a way that systematically ignores experimental results." (p.114-115)

Even though I do not describe language in terms of computations/representations, I could not agree more with Poeppel and Embick that linguistic theory should be informed by experimental results, and as I am interested in what is *really* in the mind/brain I only posit linguistic constructs which I claim could be such realities. For this reason I find functionalist theories of language attractive since they stick close to what is known about motor and perceptual systems. It may be the case that not everything in language or even phonology can be accounted for by motor and perceptual constraints, however it seems reasonable to me to start by first ruling out this possibility before adding constructs to one's ontology. For the purposes of my dissertation, phonological facial movements can be well accounted for with the working assumptions presented in my introduction.

In what follows I present two studies aimed at providing further empirical evidence for my assumptions, and I also present a review paper on the relationship between emotion-related facial expressions and facial movements used as linguistic elements. In the first study I tested the possibility that deaf persons can use mouthings as the basis for their phonological representations of spoken German. I hypothesized that if deaf individuals automatically access phonological representations based on mouthings during reading of German, that they will display a 'pseudo-homophone' effect, i.e. slower reaction times to pseudo-homophonic non-words (BRANE) compared to non-pseudo-homophonic non-words (BLANE). In the second study, I aimed to establish whether emotion related facial expressions are regularly used as part of the signs for emotion concepts in German Sign Language. I assessed this by gathering a corpus of German Sign Language emotion related signs.

1. Study One

A Dual-Route Cascaded Model of Reading by Deaf Adults: Evidence for grapheme to viseme conversion.

Eeva A. Elliott 1, Mario Braun 1,2, Michael Kuhlmann 1, and Arthur M. Jacobs1,2

1 Freie Universität Berlin

2 Dahlem Institute for Neuroimaging of Emotion (D.I.N.E.)

Abstract

There is an ongoing debate whether deaf individuals access phonology when reading and if so, what impact the ability to access phonology might have on reading achievement. However, the debate so far has been theoretically unspecific on two accounts: 1) the phonological units deaf individuals may have of oral language have not been specified 2) there seem to be no explicit cognitive models specifying how phonology and other factors operate in reading by deaf individuals. We propose that deaf individuals have representations of the sub-lexical structure of oral-aural language which are based on mouth shapes, and that these sub-lexical units are activated during reading by deaf individuals. We specify the sub-lexical units of deaf German readers as 11 'visemes', and incorporate the viseme-set into a working model of single word reading by deaf adults based on Coltheart et al.'s (2001) Dual Route Cascaded Model of reading aloud (DRC). We assessed the indirect route of this model by investigating the 'pseudo-homoviseme' effect using a lexical decision task in deaf German reading adults. We found a main effect of pseudo-homovisemy suggesting that at least some deaf individuals do automatically access sub-lexical structure during single word reading.

Keywords: deaf reading, phonology, visemes, DRC

It is well documented that deaf individuals lag behind the hearing in reading age (Traxler, 2000; Wauters, Van Bon, & Tellings, 2006). In an attempt to understand why deaf readers lag behind their peers, much research in the field has focused on identifying the potential underlying skills that contribute to deaf reading competence. Various skills, such as Sign Language competence, phonological awareness, speechreading skill, and vocabulary, have been correlated with reading achievement, but there is disagreement regarding which of the implicated skills are crucial for high reading achievement by deaf individuals, and why. In contrast to research on word recognition in hearing persons, the current debates concerning reading by deaf individuals do not offer proposals that describe and model the specific cognitive processes involved when deaf individuals read.

Even though reading ability of deaf individuals is probably a too complex behavior to be explained by one factor alone, the literature still reflects a tendency to emphasize one skill over another, without making specific and detailed models attempting to explain exactly how all of the factors, or one supposedly crucial factor, operate together in the act of reading.

Paul and Lee (2010, p. 459) for example, state; "Reading is a complex cognitive activity, and no single factor can account for the complete range of difficulties that impede the reading development of individuals". In their 'qualitative similarity hypothesis' they claim that deaf readers develop reading skill in a qualitatively similar fashion to their hearing peers, only quantitatively delayed. However, without describing exactly how the hearing read, this hypothesis remains too general to allow experimental tests. As there is still an intensive ongoing debate regarding the relative contributions of orthography and phonology in hearing readers and dyslexics (Alvarez, Carreiras, & Perea, 2004; Frost, 1998; Stenneken, Conrad, Hutzler, Braun, & Jacobs, 2005) the 'qualitative similarity hypothesis' seems to be a limited research tool, unless its authors specify which of the competing computational models of hearing reading they find most convincing (Coltheart et al., 2001; Grainger & Jacobs, 1996; Perry, Ziegler, & Zorzi, 2007; Zorzi, 2010). Secondly, there needs to be an explanation of the mechanism that delays deaf individual's reading competence in comparison to hearing readers. Also, an explanation is required of the fact that some deaf readers are not simply delayed in reading development; rather, they never actually do reach hearing levels of reading as reflected in the reading quotients of the adult participants in our experiment, provided in the results section below.

Hermans et al. (2008a) also point out the lack of specific models of reading by deaf individuals. They develop a model which specifies how bilingually educated deaf children acquire written language vocabulary. Their model describes three stages through which an orthographic lexical entry is incorporated into a child's mental lexicon. In the first stage an association between a Sign word and the written cognate is established. At this point, the lexical entry contains only orthographic information, but no morphological, syntactic, or semantic specifications. In the second stage the semantic and syntactic specifications of the Sign lemma are copied into the lexical representation of the orthographic word. At this stage, the sign language system is not necessarily involved in the recognition of the written word. In the last stage the morphological specifications for the orthographic word are filled in and the connection to the conceptual system is independent of the Sign Language system. The authors also provide experimental evidence for the activation of the Sign cognates during reading (see

also Morford, Wilkinson, Villwock, Piñar, and Kroll (2011) for evidence of American Sign Language activation during English reading). This model provides a specific description of how written language vocabulary can be acquired by deaf children in a particular setting, and it offers an account of the correlations that will be mentioned below between Sign Language skills, productive vocabulary, and reading skill. However, the model is not informative regarding the possible contribution of phonological awareness, recoding, and speechreading to deaf individuals' reading skill.

Below, we present some of the skills that are thought to have a major impact on deaf individuals' reading competence, focusing mainly on phonological skills and speechreading, as these are relevant to our experiment. However, this does not constitute a comprehensive review of all the research on all related skills. We then address terminological issues and finally we present our working model of word recognition in deaf readers.

Skills Related to Reading Comprehension amongst Deaf Individuals

One of the most debated issues in the deaf reading literature is whether deaf individuals have phonological representations of oral-aural languages and if so, whether they automatically make use of these representations when reading. Based on deaf participant's performance on rhyme judgments, Dodd and Hermelin (1977) suggested that deaf individuals have representations of the sub-lexical structure of English based on speechreading. The studies that followed since, assessing whether or not deaf individuals have phonological representations of written words, have produced mixed results. A meta-analysis of studies on phonological coding and awareness (PCA) amongst deaf readers by Mayberry, Giudice, and Lieberman (2011) found that of the studies meeting their inclusion criteria 16 reported evidence of PCA, 20 reported no evidence of PCA, and 11 reported evidence of PCA for a subgroup. In general their results showed that PCA predicts 11% of reading proficiency variance in the deaf population. For additional reviews of PCA in deaf readers see (Paul, Wang, Trezek, & Luckner, 2009; Perfetti & Sandak, 2000; Wang, Trezek, Luckner, & Paul, 2008). A longitudinal study by Colin, Magnan, Ecalle, and Leybaert (2007) seemed to show that phonological awareness is predictive of reading skill for deaf individuals. They found that phonological awareness, measured using a rhyme decision and rhyme generation task, in 21 deaf and hearing pre-readers predicted written word recognition scores one year later. However, a longitudinal study by Kyle and Harris (2010) showed a more complex pattern of findings, as described below.

Rhyme judgment data suggest that at least some deaf individuals can activate some form of phonological code for written words when required to do so. However, the ability to make correct rhyme judgments when asked to do so does not provide strong evidence that phonological codes are automatically accessed during reading. A stronger case could possibly be made, if a pseudo-homophone effect - a valid marker of well-functioning phonological recoding in hearing readers as measured by the lexical decision task (Braun, Hutzler, Ziegler, Dambacher, & Jacobs, 2009; Ziegler, Jacobs, & Kluppel, 2001)– could be demonstrated in deaf readers, suggesting that they automatically access phonological codes while reading. The reason is that in order to perform a visual lexical decision the activation of phonological codes in principle is not required. It is actually a hindrance to performance, as far as pseudo-

homophones (BRANE, FOCKS) are concerned. Beech and Harris (1997) used a card sorting lexical decision task with deaf children. They did not find significant regularity or homophony effects. Transler and Reitsma (2005) replicated the Beech and Harris study with better controlled stimuli and did find a pseudo-homophone effect for deaf children. Note that both of these studies only measured error rates. Ormel, Hermans, Knoors, Hendriks, and Verhoeven (2010) used a picture-word verification task with deaf children, but did not find a significant effect of pseudo-homophony.

In summary, there is some evidence for phonological awareness and recoding in at least some deaf individuals. However, whether phonological codes are automatically accessed during reading and how PCA is related to reading achievement is not clear. Furthermore, to the best of our knowledge, no study has specified the possible phonological units activated by deaf individuals, beyond the assertion that they may be derived from speechreading.

Harris and Moreno (2006) aimed to identify the skills of good deaf readers. They directly compared good and poor reading groups. They measured phonological coding in deaf individuals by counting the percentage of phonetic errors in spelling and in counting syllables. They also looked at orthographic awareness, speech intelligibility, and accuracy in speechreading. From their results they concluded that speechreading ability was probably the underlying skill used by good readers. Within the Good Reader group were individuals both with good and poor phonological skills; however they all had good speechreading skills. They also suggested that speechreading alone is not enough. Other factors such as vocabulary size may also determine reading ability. Kyle and Harris (2006) also found productive vocabulary and speechreading skill to be the significant predictors of reading for deaf individuals.

Kyle and Harris (2010) conducted one of the few longitudinal studies on deaf reading skill. Their results suggest that speechreading skill is predictive of later reading skill. The authors assessed the role of phonological awareness, productive vocabulary, speechreading, and short term memory, over a three year period, for a group of 29 deaf children, to assess what impact each skill had on reading outcome. They found that earlier vocabulary and speech reading skills predicted longitudinal growth in reading achievement, while earlier reading ability was related to later phonological awareness. Speechreading was a significant predictor of word reading ability for the first time period, whilst vocabulary was consistently predictive across all measured time periods. The authors interpret this finding as a possible indication that phonological skill is acquired through reading instruction for deaf individuals, and not the other way round, and that speechreading provides the basis from which deaf individuals create their phonological codes of oral-aural language. Findings in Kyle and Harris (2011) showed that speechreading was also a longitudinal correlate of reading and spelling for hearing children as well as deaf children. Further support for the idea that speechreading is the source from which deaf individuals derive phonological units can be found in (Hanson & Fowler, 1987; Leybaert, 2000; Mohammed, Campbell, Macsweeney, Barry, & Coleman, 2006). We propose that the next step in this line of research is to put forward a specific set of phonological units that are derivable from speechreading, to offer a model of how these units are used to read, and to test this model. This is what we attempt to do in our experiment, as described below.

Most of the studies mentioned above did not control for the Sign Language skills of the participants. Chamberlain and Mayberry (2008) found that ASL skill correlates with English reading skill. Hermans, et al. (2008b) also report a strong correlation between Dutch Sign Language vocabulary skills and written Dutch skill. They propose a model of how competence in a Sign Language can contribute to competence in a written oral-aural language Hermans et al. (2008a).

Miller (2010) found that phonological awareness was not predictive of reading comprehension skill. Rather, he found that knowledge of the syntactic structure of written Hebrew underlies reading comprehension skill. He discusses deaf individuals' reading skill in terms of two reading strategies, a semantic strategy, and a syntactic strategy. He proposes that developing syntactic knowledge of poor readers would be a better educational policy than focusing on phonological awareness.

Visemes – the 'phonemes' of deaf readers?

In order to better understand the mixed findings on phonological recoding by deaf individuals during reading, we propose a specific hypothesis on what the phonological codes of deaf individuals are and how they are acquired. We incorporate this code into a tentative working model of single word reading for deaf individuals.

Firstly, we wish to make one point regarding terminology. The term 'phonology' is often used in a different sense in the literature on deaf reading skills than it is used in the Sign Language literature. In the former, it usually refers to sub-lexical structure that is acoustically manifested, i.e. abstract representations of concrete sounds. This is etymologically correct, since 'phone' means 'sound'. In this regard, it makes sense to say that deaf individuals have impoverished phonology as in the example below:

"[…] a major source of difficulty for many deaf readers is *impoverished phonological knowledge*." [italics mine] (Beech & Harris, 1997, p. 106)

However, 'phonology' has taken on a broader meaning since the first linguistic studies of American Sign Language in the 1960's (Stokoe, 1960) and has come to mean the abstract representations of sub-lexical units of any modality, visual or acoustic. Sign linguists generally use the term in its broader sense. In this sense, the quote above is inaccurate, since deaf children exposed to Sign from an early age on acquire normal phonological knowledge of their own language, and this is not hindered by auditory deprivation. What they perhaps lack are full representations of the phonologies of German, or English or whichever language is used by the hearing community within which they live. We will use the term 'sub-lexical structure' hereinafter to refer to the phonologies of languages both of hearing and deaf individuals, as this is a modality independent term.

By definition phonemes are abstract mental units, for this reason it is stated in Paul et al. (2009, p. 348) that they do not necessarily need to be heard; "Actually we refer to phonemes as abstract entities that do not necessarily need to be heard or spoken (in isolation or as part of blending or segmenting)". This notion is problematic for the following reason; phonemes are abstract, but they are acquired through exposure to concrete sensory input. To develop the full

phonemic repertoire of any language, one needs to be exposed to that specific language, preferably at a young age. McQuarrie and Parrila (2009) present evidence that deaf individuals do not have sub-lexical representations of English that are equivalent to that of the hearing. They conclude that sub-lexical structure cannot play an important role in deaf reading skills. In contrast, we propose that deaf individuals do have abstract representations of the sub-lexical units of Spoken Languages. However, these units are not identical to the sub-lexical units of their hearing peers, because they are derived from the visual sensory input alone. We call these units visemes ('visual-phonemes') following Fisher (1968).

McQuarrie and Parrila (2009) note that positive findings of sub-lexical effects in deaf individuals are mostly from two-choice discrimination experiments, in which the choice could have been made on the basis of 'tactile or visual similarity'. They state that what have been reported as phonological effects may have been caused by not controlling for tactile and visual similarity between phonologically similar words. As stated before, we do not claim that deaf individuals have a phonological repertoire that is identical to their hearing peers, but that based on the very visual or tactile stimuli McQuarrie and Parrila (2009) present as a confound of phonological similarity, they can develop a repertoire of visemes which may be activated when they read.

Construction of the German Viseme Set of Deaf Readers

Auer (2009) carried out a four step process in deriving the visemes for English in his studies of speechreading which is very similar to the one we carried out for deriving the visemes of German. The steps are; (1) development of segmental retranscription rules to represent only visually perceptible segments. He does not use the term viseme; instead he uses the term Phoneme Equivalence Class (PEC). (2) Application of retranscription rules to all words in a phonemically transcribed word database, (3) sorting of words into lexical equivalence classes (LECs), which I call homovisemes. (4) Use of quantitative measures on information in the retranscribed word database. Auer used twelve PECs for English, compared with the eleven visemes we define for German. For highly skilled speech-readers Auer uses 19 PECs. However, Auer does not apply his work to the issue of reading skill.

In our attempt to define the viseme set of deaf readers of German, we analyzed videos of mouthings taken from the German Sign Language ("Deutsche Gebärdensprache"; DGS) dictionary (Kestner & Hollmann, 2009) as the realization of mouthings by deaf people. We chose to derive our viseme set from mouthings produced by deaf individuals in the context of DGS, instead of from German speechreading for the following reasons:

Mouthings (not to be confused with mouth-gestures) in DGS lexical items are identical to the mouthing caused by articulating the German equivalent. Mouthings occur frequently in DGS (Ebbinghaus & Hessmann, 2001) and can serve to disambiguate signs that have the same manual component (such as SISTER and BROTHER). Although the linguistic status of mouthings in Sign Languages is under debate (Boyes Braem & Sutton-Spence, 2001), in DGS at least they are used and perceived frequently. We reason that it may be better to use visemes that are actually produced by deaf people, as a deaf person must have a representation of that viseme in order to produce it. Had we just used what deaf individuals see, rather than produce, we would have a weaker basis to claim that these units are mentally stored. For

example a foreign language learner can be exposed to new phonemes, but if she cannot produce them, it is harder, though not impossible, to judge whether she can distinguish these new phonemes when perceiving them.

We went through a list of German phonemes, given in Table 1 below in CELEX notation (Baayen, Piepenbrock, & Gulikers, 1995), and looked for examples of their mouthing in the DGS dictionary. We thus could distinguish 11 different mouth shapes shown in Table 1.1.

Table 1.1 Visemic Inventory of DGS

Phoneme (CELEX notation)	Viseme	Description
b m p	P	Lips compressed
d n s t z	T	Lips slightly apart with tongue in contact with teeth
@ N g h k r x	-	Relaxed medium opening of mouth
l	L	Open mouth, tongue contacts alveolar ridge and drops
f v	F	Pouting of the lips while teeth stay together
I i j	I	Spreading of lips slightly open
E e	E	Medium opening of spread lips
a	A	Wide opening of mouth
& O Q o	O	Rounding of lips
U Y u y	U	Pouting of lips

Starting with the bilabial stops, we searched for German words in which /p/, for example, appears word initial and before the vowel /a/, as in the word 'Paste'. We looked at word initial position as this provided a clear point of onset. We chose pre-/a/ position on the rationale that the maximal opening of the mouth for this phoneme would also give us an as-clear-as-possible visible point of reference for the termination of /p/. We then took a snapshot of the mouthing, and compared it with /p/'s occurring in other environments, such as word medial, or word final, and before different vowels. In such environments the mouthing was co-articulated: for example, there was lip rounding in pre-/o/ position. We assigned the symbol /P/ to this mouthing, and described it as the 'lips compressed' viseme /P/. Finally, we compared the viseme /P/ in our first snapshot with its realization by two other speakers of DGS, to filter out individual differences in articulation.

In the next stage, we followed the same steps for the German phoneme /b/. According to our analysis, it is visemically identical to /P/, as is /m/. So the three German phonemes /p, b, m/ map onto the viseme /P/. We then repeated this procedure for all German phonemes. We searched for vowels in word initial and pre-/P/ position, as the compression of the lips for /P/ gives a clear indication of the vowels termination. Using this procedure, 11 visemes could be clearly identified.

The neutral viseme /-/ is an interesting case that deserves careful future study. In word initial position, we did not always find any visible evidence of its existence. In the entry for 'Gala' there is clearly a neutral mouthing before the /A/ viseme, but in 'Kabel' this is less clear. The same applies for its occurrences in other positions. In word final position however, where a reduced vowel would be in German, it is usually clearly seen. Although /-/ appears to be particularly prone to co-articulation, one can speculate that it may have significance as a timing slot, and therefore should be represented in a visemic transcription of mouthings. For this reason, we chose the dash as its symbol, to indicate that it holds a space in time, but has only minimal visual features.

We then converted the CELEX German database into visemic transcription and calculated the frequencies of the 11 visemes as shown in table 1.2:

Table 1.2 Type Frequency Values of the 11 German Visemes

Viseme	Number of occurrences in CELEX (type)	% Occurrences per total occurrences
-	119728	25.66
T	113810	24.39
A	40022	8.57
I	38161	8.18
P	31695	6.79
U	24794	5.31
E	23559	5.05
L	23222	4.97
F	21456	4.59
O	17894	3.83
S	12167	2.60
Total occurrences	**466508**	

We then assessed how many lexical entries in our visemic lexicon were homovisemic (analogous to homophonic). Out of 51728 entries in the CELEX database, 87% (45101) are unique (not homovisemic with any other entry). Out of the total high frequency words (more than 20 occurrences per million) 83% are unique entries (2920 of 3535).

Taking into account the amount of exposure deaf individuals have to mouthings, and Auer's (2009) findings of frequency and neighborhood effects for speech-read words it is plausible that deaf individuals do indeed naturally acquire a set of visemes. Deaf individuals are exposed to mouthings in several different contexts: As described in Ebbinghaus and Hessmann (2001) speech-reading is used in communication between deaf and hearing

individuals, although it is described as being inefficient. Manually Coded German, which is frequently used in educational settings for deaf individuals, is also a context in which mouthed German words are accompanied with manual signs. Lastly, in DGS, mouthings that match the German cognates of signed words occur together with a manual component. Within DGS, mouthing occurs at roughly one mouthed word to every two manual signs. Furthermore, the findings of a correlation between speechreading skill and reading skill in deaf children (Harris & Moreno, 2006; Kyle & Harris, 2006; Kyle & Harris, 2010; Kyle & Harris, 2011) described above would also indicate that a naturally acquired viseme set from speechreading could be utilized in the process of reading by deaf individuals. Our viseme set and DRC model of reading by deaf adults described below is a specific proposal of how exactly speechreading could provide the basis from which deaf individuals create their sub-lexical codes of spoken languages.

Despite the fact that DGS mouthings are identical to the mouthing caused by articulating the German cognate, we nevertheless compare our set derived from deaf mouthings to a viseme set taken from the realization of German mouthings by hearing German speakers. Aschenberner and Weiss (2005) constructed a viseme set for German which consists of 15 units. They for example assigned /p,b/ a common viseme, but /m/ was a assigned a separate viseme because the lip compression lasted longer than for /p/ and /b/. It is important to note that had we adopted the Aschenberner and Weiss set, this would not have altered the architecture of the DRC model, nor would it have altered our predictions or the manner in which we designed our experiment as we explain below. It is also possible that each deaf person has a slightly different number of sub-lexical units depending on the amount of residual hearing they have – which may give them access to acoustic distinctions in addition to visual distinctions – or simply because some deaf individuals may be more skilled at differentiating the visual features. For example, it is possible that some deaf people distinguish /m/ as visemically different to /p,b/ as reflected in Aschenberner and Weiss' set. Essentially, the more sub-lexical units one proposes deaf individuals have access to, the closer reading by deaf individuals should approximate hearing reading levels, but the architecture of the system that processes the units remains the same for both deaf and hearing people.

The Dual Route Cascaded Model of Reading by Deaf Adults

Dual route models of reading have been referred to in the deaf reading literature (Beech & Harris, 1997), but so far no hypothesis as to exactly what kind of dual route system would accurately model reading by deaf individuals has been offered. Also, no specific sub-lexical units have been defined for the indirect route, beyond stating that it is possible that deaf individuals have sub-lexical representations based on speechreading. Compared to the detailed and empirically well-backed models of hearing reading (Jacobs & Grainger, 1994), the deaf reading literature still requires theoretical development and model building. As explained in (Coltheart et al., 2001) the benefit of implementing a theory as a computational model is that computational modeling requires full specification of a process, as a computer program will not run unless fully specified. This forces theorists to make very precise theoretical commitments. When a model does not work, it leads either to adjustments of the model, or to a rejection of it. Furthermore, computational models also predict behavior on certain tasks, which can then be experimentally verified on humans. If the prediction is not

supported, the model must then be modified to account for the new data. They do of course caution that even though a computational model may function and account for all existing empirical data, this does not rule out the possibility that another model with a very different architecture could be developed that can do the same tasks. Should two competing models exist, they can be tested against each other by devising a new task that would elicit different behaviors from each model given their architecture. Whichever model more accurately mirrors human behavior on this new task would then have to be accepted as the better model. Below I describe in some detail how and why Coltheart and colleagues developed the dual route cascaded model of visual word recognition and reading aloud (DRC), and how and why we adopt this architecture to describe reading by deaf individuals. For an in depth understanding of the model, the DRC is available as a freely downloadable program at: http://www.maccs.mq.edu.au/~ssaunder/DRC/

The DRC model describes how one syllable words of up to eight letters that are visually perceived as print are converted to a string of phonemes that allows the system to respond on a lexical decision task or to read the phoneme string aloud. The architecture of the model is hand wired rather than learnt through an algorithm. The reason for this being that the developers of the model preferred relying on an architecture that is motivated by empirical findings on human behavior rather than backpropagation, since backpropagation can generate architectures that may not reflect what research indicates to be true of the actual architecture of the human cognitive system for reading. The following are some of the architectural choices made by the developers of the DRC model: Processing is cascaded not threshholded. That is, activation spreads from one layer to another automatically without the requirement that activation in the layer reach a certain threshold before flowing down. They also use local rather than distributed representations for words. Sub-lexical processing takes place at the phoneme level. That is, graphemes (a single letter or a group of letters such as: a, b, gh, ph) associate with a single phoneme. Furthermore they follow the GRIN principle of computational modeling which means: activation is graded instead of all-or-none, it is random, it is interactive (information flows bidirectionaly), and it is non-linear. For a detailed account of the empirical evidence from humans that motivates each of these choices, see (Coltheart et al., 2001) and references therein.

Figure 1.1 The dual-route cascaded model of visual word recognition and reading aloud, reprinted with permission from Coltheart et al. (2001)
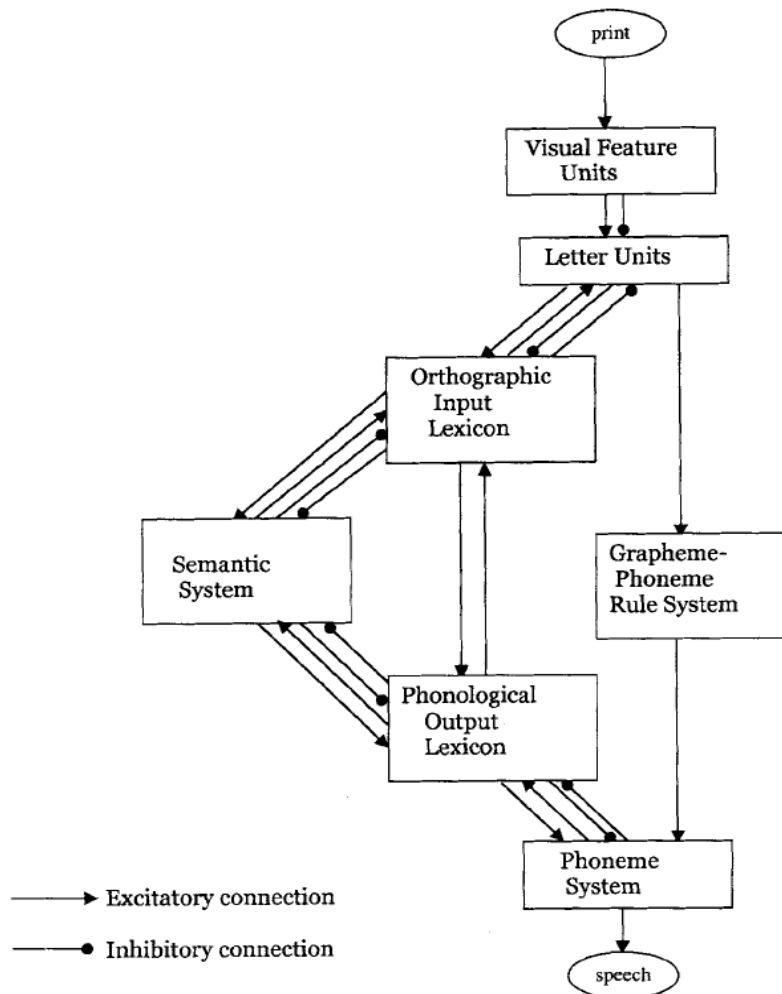
The DRC model converts print to phonemes in the following manner: The first two units in the model reflect early visual perception. On encountering printed words, visual features that are activated in the visual feature unit layer activate or inhibit individual letters in the letter unit layer. For example seeing the letter (t) would activate all letter units that share the visual feature of a cross, such as (f) and inhibit all letters that lack this feature such as (l). In this manner many non-target letters receive activation, but after a sufficient amount of cycles the target letter (t) will have the greatest amount of activation. From the letter units downwards the task is to convert the letter string into a phoneme string that is available for a response by the system such as reading or deciding if the string is a word or not. The letter units send activation down three routes to the final destination of the phoneme system; the semantic route, the lexical route and the sub-lexical route. As this is a cascaded process, activation spreads down all three routes simultaneously and all three routes interact with each other and affect the behavior of the system. Despite having three routes, the DRC model is called a dual route model because only the lexical and sub-lexical routes are implemented in the computational model. The lexical route (also called the direct route) consists of an orthographic input lexicon and a phonological output lexicon. The orthographic lexicon

contains 7,981 units corresponding to all monosyllabic words of up to eight letters in the CELEX database (Baayen, Piepenbrock, & van Rijn, 1993). The phonological lexicon contains 7,131 units. The reason that there are more entries is the orthographic lexicon than the phonological lexicon is because of homophony. That is MEAT and MEET are separate entries in the orthographic lexicon but only one entry /mi:t/ in the phonological lexicon. A letter in the letter unit layer will activate all lexical entries that share that letter in that position and inhibit all those that don't. For example (m) in first position will activate MEAT and MOON but inhibit SOON. Once all the letters have fed their activation downwards one entry in each lexicon will have received more activation than all the others. Activation from the lexicons will activate single phonemes in the phoneme system. The phoneme system contains 43 units corresponding to 43 English phonemes plus a blank unit. The blank unit is required to indicate the end of a letter or phoneme string. In this layer a phoneme string is assembled which is available for output as speech. The phoneme system will also simultaneously be receiving activation from the indirect route (also called the sub-lexical route). This route consists of a layer that uses rules to convert graphemes into phonemes. For example (t) will be converted into /t/, (gh) occurring at the end of a word will be converted into /f/. In summary the visual input MEAT will be converted to a string of letter units which activate or inhibit a number of entries in the orthographic and phonological lexicons which activate phonemes in the phoneme system. It will also activate a rule system that assigns a grapheme to a phoneme through prespecified rules. At the end the string of phonemes /mi:t/ in the phoneme system receives the most amount of activation from both routes and can be used by the system to respond to any of the three following tasks: lexical decision, reading aloud, and perceptual identification. The DRC model has also been implemented in German (Ziegler, Perry, & Coltheart, 2000).

Note that the layers in this model interact with each other bi-directionally, except for the two first layers which only feed information forward. Interaction between layers and within a layer can be both excitatory and inhibitory, with the exception of the connections between the orthographic lexicon and the phonological lexicon, which are only excitatory. This means that the indirect and direct routes can activate or inhibit each other. Additionally, the lexicons are frequency sensitive: activation for high-frequency words rises faster than for low-frequency words.

In figure 1.2 below we present our proposal for a DRC model of how deaf individuals read, closely following the structure of the original DRC model. We specified 11 sub-lexical units for German reading based on mouthings, called visemes. The role of these visemes in reading for deaf individuals is hypothesized to be identical to that of phonemes for the hearing. That is, whereas in the DRC model there exist 43 units for each phoneme plus a blank unit in the phoneme system, the DRC model of reading by deaf individuals would contain 11 units for each viseme in the viseme system plus a blank unit. In other words we propose that the architecture used by deaf and hearing individuals for reading is fundamentally the same. We hypothesize that the differences between these populations lie not in the architecture of the cognitive system but in the amount and type of units in the grapheme-phoneme rule system, the phonological output lexicon, and the phoneme system. Note however that at this point in time our model has not been implemented computationally so it remains a verbal model. (See

Jacobs and Grainger (1994, p. 1312) for a discussion regarding verbal and algorithmic models).

Figure 1.2 A Dual Route Cascaded Model of Reading by Deaf Adults
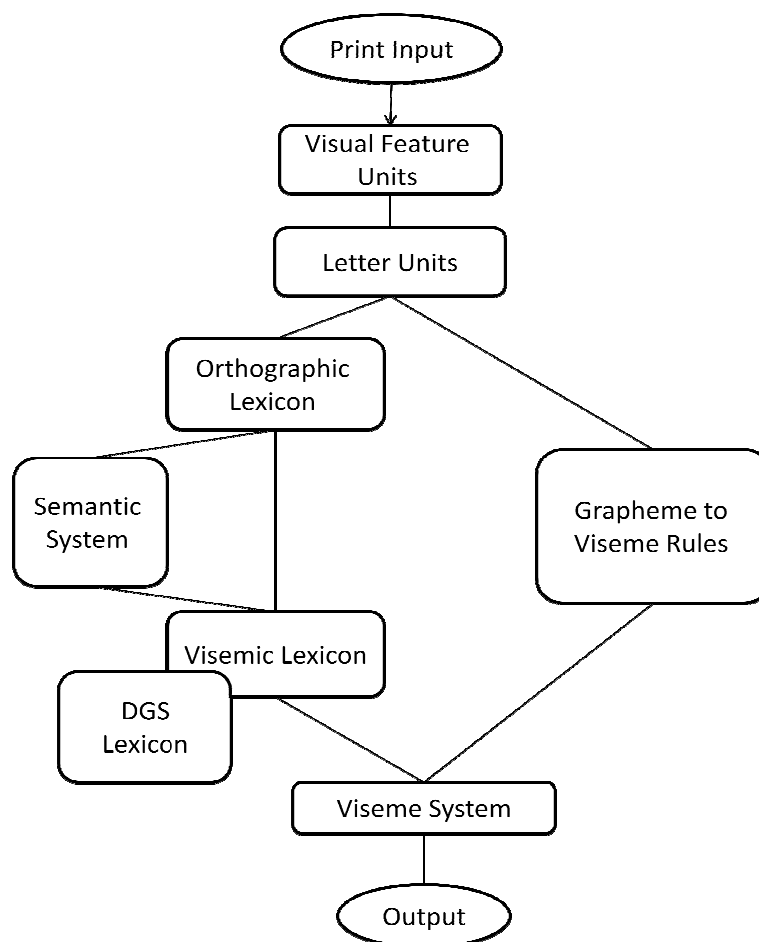
As an illustration of how the DRC model of reading by deaf adults would work, let us take the printed German input 'Mann' ('man' in English) as an example: The visual features of the word will activate letter detectors in the letter layer that share the input features and inhibit those which don't. The letter units, in turn, will activate words in the orthographic lexicon that have the input letters in their specific positions, and inhibit those that don't. The orthographic word form 'Mann' will then activate its corresponding viseme form, [PAT]. [PAT] activates individual visemes in the viseme system, which feeds back into the visemic lexicon. Note that – according to our analysis – [PAT] is homovisemic (analogous to homophonous) for eight entries in the CELEX database, for example the words 'Matt' (English: Matt) and 'Bann' (English: a Spell). So, for deaf people, eight different entries in the orthographic lexicon could activate the same visemic lexical entry. At the same time, the Grapheme-Viseme-Conversion (GVC) route will also be active. Using a set of rules, the GVC route will convert graphemes into a string of visemes. 'M' will be converted to [P], 'a' into [A], and 'nn' into [T]. These viseme codes will activate individual visemes in the visemic system, through which the GVC route can also activate the visemic lexicon. Note that in Coltheart et al., (2001) the authors emphasize that both routes of the model are always active and not completely independent, for they receive input from the same layer, and feed output to a common layer which in turn feeds back to the visemic (or for hearing people the phonological) lexicon. They thus state

that 'horse race' metaphors to describe the two routes of the model are inaccurate and also not supported by empirical findings.

The DRC model proposed by Coltheart et al. (2001) which we adopt for deaf readers does not include a level to account for bilingual readers. However there is evidence that L1 and L2 lexicons are both activated during reading tasks in either one of a bilingual's languages (Dijkstra, Hilberink-Schulpen, & Van Heuven, 2010; van Heuven & Dijkstra, 2010; van Heuven, Dijkstra, & Grainger, 1998). This also seems to be the case for Sign Languages (Morford, Wilkinson, Villwock, Piñar, & Kroll, 2011). We therefore include in our model the DGS lexicon as a separate lexicon that overlaps with the German Visemic lexicon. Activation from the DGS lexicon could feed into the system following the same general principles of modeling mentioned above, namely through cascaded activation and inhibitory and excitatory connections within the layer and between layers. However, our model remains a verbal model as yet. We have not implemented it computationally and therefore do not yet know if such a structure would simulate reading by deaf individuals.

The question of whether deaf people access sub-lexical structure while reading can be better tested once the sub-lexical units involved and their role in the reading process are actually specified. Earlier studies which report behavioral responses of deaf readers suggesting that they are using a dual route system have not offered a possible description of the sub-lexical units involved. Although, as mentioned above, it has been suggested that deaf individuals can derive sub-lexical units from speechreading, to the best of our knowledge, no study has made an explicit inventory of the hypothetically involved units. However, the DRC model of reading by deaf adults sketched above and the included German viseme set is only a first step towards a fully specified model of single word reading by deaf individuals. We address the need for further development in the discussion section below.

We emphasize that we propose that the cognitive architecture used for reading by hearing and deaf individuals, as well as various sub-groups amongst the deaf population is fundamentally the same. The DRC model could account for reading by various sub-groups of the deaf population in the following manner:

Individuals with a greater amount of aided or unaided residual hearing might have access to more phonological contrasts than those relying on visual input only. For such a reader it may be that they have access to say 20 or more sub-lexical units derived from audio-visual input, as opposed to 11 sub-lexical units which can be derived from visual input alone (visemes). The closer an individual's hearing is to normal levels, the closer their reading should approximate normal reading levels all else being equal.

More experience with a language that is fully accessible to them (i.e. a Sign Language) from an early age could result in a child coming to school with a larger semantic system and a large sign language lexicon that may facilitate the acquisition of a large orthographic lexicon, perhaps via the process proposed in (Hermans, Knoors, Ormel, & Vcrhoeven, 2008a).

Deaf individuals raised in a predominantly oral environment may have stronger visemic representations, and perhaps display a stronger pseudo-homoviseme effect. In addition they would not have a Sign Language lexicon that would interact with their reading.

Methods

In order to test whether deaf individuals access sub-lexical information while reading, as hypothesized in the GVC route of our DRC model of reading by deaf adults, we investigated the pseudo-homoviseme effect using a lexical decision task. The lexical decision task (LDT) is a well established paradigm in psychology and psycholinguistics (first used in the early 1970's by Meyer and Schvanenveldt (1971)) in which a participant is presented with a letter string that is either a word (BRAIN) or a non-word (BLANE). The participant is asked to indicate whether the letter string is a word or not usually by button press. For hearing readers the following effects are well attested and also simulated by the DRC model (Coltheart et al., 2001, p. 228): high frequency words are accepted faster than low frequency words; words are accepted faster than non-words are rejected; low frequency words with dense neighborhoods are accepted faster than low frequency words from sparse neighborhoods; pseudo-homophonic non-words (eg. BRANE) take longer to reject than matched non-word spelling controls (eg. BLANE). We hypothesize that if visemes are activated during single word reading for deaf individuals, pseudo-homovisemes will take significantly longer to reject than their matched spelling controls.

Participants

Twenty three right handed deaf adults (eight male, mean age 34 years) participated in this study. All participants reported a severe to profound hearing loss (70dB or above) from birth. None of them had cochlear implants. All reported normal, or corrected to normal vision. Two participants were excluded from the analysis, one for misunderstanding the instructions, and one for having average response latencies longer than 1000ms across all trials. Trials with response times below 200 ms and above 2000 ms were excluded from analyses.

Average age of first exposure to German Sign Language (Deutsche Gebärdensprache: DGS) was 7.4 years of age, and four participants were native signers (born to at least one signing parent), ten were early DGS acquirers (between 1-5 years) and the remaining seven were late acquirers (5 years and above, maximum age 23).

All subjects were primarily educated in German with Lautsprachbegleitende Gebärden (Manually Coded German). Eleven also received education in DGS at university level or at special vocational courses. Table 1.3 gives the amount of time participants spend reading per month.

Table 1.3 Reported time spent reading per month

Time spent reading per month	Books	Newspapers	Internet
	Number of participants		
Above 10 hours	8	8	13
5-10 hours	4	0	3
1-5 hours	3	8	5
Less than 1 hour	5	4	2
0 hours	2	3	0

Note. Data on book reading was missing for one participant

Stimuli

The stimuli were adapted from a well-controlled set used with hearing participants (Braun et al., 2009). Our set consists of 280 items. Half of the items are words, half are non-words. Half the words are of high frequency, and the other half of low frequency. The non-words were constructed from high (more than 20 occurrences per million) and low (less than 20 occurrences per million) frequency base-words in which one letter was altered, while keeping word-likeness high. A base word such as 'Reich' ('empire'), for example, was altered to the pseudo-homophonic version of 'Raich', and also to an orthographic control of - 'Reuch'. The non-words were all three to five letters (one to two syllables) in length.

Table 1.4 Example of how stimuli were created and their visemic representation

	Base word from which the non-word stimuli were generated	Pseudo-homovisemic non-word	Spelling control non-word	Word
	REICH	RAICH	REUCH	AFFE
Visemic notation	[-AI-]	[-AI-]	[-OI-]	[AF-]
English gloss	Empire			Ape

Note. The base words used to generate the non-words were themselves not used as stimuli

We converted all the original stimuli from the (Braun, et al., 2009) experiment into visemic transcription. Some of the spelling controls from the Braun study visemically are words even though phonologically they are not. For example: the control word 'Bid' transcribed according to our viseme set is /PI:T/. /PI:T/ is the visemic realization of the word 'mies' ('appalling'), so we rejected the pair 'Bat' and 'Bid' as stimuli for deaf readers, as it may activate the lexical entry for 'mies' and create a confounding effect. The control non-word for the pseudo-homoviseme 'raich', which is 'reuch' [-OI-], is not homovisemic for any other entry in the CELEX database (Baayen, et al., 1995), so we accepted this pair as suitable stimuli.

Procedure

Participants were asked to fill in a background questionnaire. The questionnaire included a section on their hearing level, on their exposure to different languages during education, the amount of time they spend reading, and age of DGS acquisition. They were then given a 20 item spelling test, in which they were shown a DGS sign from a video, and asked to write the corresponding German word. Afterwards, they were given the Salzburger Reading Fluency test (Hutzler & Wimmer, In preparation). This test consists of making a true or false semantic judgment on sentences. There are 77 items on this test and participants are given three minutes to judge as many sentences as they can. Participants are given one point for each correct judgment. This score is then assigned a normed reading quotient value.

Lastly, participants were seated in front of a computer and given instructions both in DGS and in written German to indicate with a button press whether a stimulus was a word or not as fast and correct as possible. They used their left and right index fingers. A break appeared half way through the experiment. They were given 10 practice trials to familiarize them with the task. The experimental trials were presented in pseudo-randomized order for each participant. Each trial began with a fixation mark in the center of the screen, which was replaced by the stimulus which stayed on the screen until button press. The stimuli were presented in white on a black screen in upper case letters Times New Roman 20pt font. The experiment, including the questionnaire and administration of the tests lasted about one hour.

Results

The average error rate on the spelling test was 1.6 out of 20.

The average reading quotient for the participants was 78, based on norms for the hearing. Normal hearing reading levels lie between 85-115, nine of the participants were within this range. The highest score was 113.

There was also a correlation between reading quotient and average reaction time ($r = -0.77$). Participants with faster mean reaction times showed higher reading quotient values.

Table 1.5 below shows the reaction time means and error rates for Pseudo-homovisemes derived from low and high frequency base-words, spelling controls derived from low and high frequency base-words, and for low and high frequency words. On average Pseudo-homovisemes were responded to slowest, followed by Spelling Controls followed by low frequency words and finally high frequency words.

Table 1.5 Reaction time means (ms) and error rates (%) for pseudo-homovisemes, spelling controls, and words

	RTs (ms)		Standard Deviations		Error Rates (%)	
	Low	High	Low	High	Low	High
PH	726.77	733.07	74.74	102.04	4.91	4.59
SC	704.83	717.97	77.31	90.14	2.46	3.95
WO	690.59	624.25	72.32	62.79	21.48	5.31

A 2 x 3 (word frequency: high vs. low by word type: pseudo-homoviseme, spelling control, and word) repeated measures ANOVA showed a significant main effect of word frequency, $F(1, 20) = 8.098$, $p = .01$, a significant main effect of word type $F(1, 40) = 26.029$, $p < .01$, and a significant interaction between word frequency and word type $F(1, 40) = 24.656$, $p < .01$. The Effect of Word frequency is caused by the Word stimuli. High frequency words were responded to faster than low frequency words. Both pseudo-homovisemes and spelling controls showed the reverse pattern; items derived from high frequency base-words were responded to slower than low frequency ones (see table 5). This difference was not significant as revealed by a 2 x 2 (base word frequency: high vs. low by word type: pseudo-homoviseme vs. spelling control) repeated measures ANOVA $F(1, 20) = 1.423$, p = .247.

The effect of word type derives mainly from faster reaction to word stimuli, but the test of within subject contrasts showed that the crucial comparison of pseudo-homovisemes to spelling controls was significant $F(1,20) = 9.928$, p =.005.

In summary we found: a significant frequency effect - deaf participants responded faster to high frequency words than low frequency words; a significant lexicality effect – deaf participants responded faster to words than they did to non-words; and a pseudo-homoviseme effect – deaf participants responded faster to the spelling control non-words (e.g. REUCH) than they did to pseudo-homovisemic non-words (e.g. RAICH).

When examining individual reaction times, all participants showed a frequency effect, four, however, did not show a lexicality effect, and six did not show a pseudo-homoviseme effect. This suggests that there are individual differences in reading strategies. However, our sample size was too small for sub-group analyses.

Discussion

Unlike many previous studies on phonological recoding in deaf readers, we did not directly attempt to measure the phonological awareness of deaf readers. Rather, we were interested in whether sub-lexical information is automatically accessed during visual word recognition, even when the experimental task does not in principle require the activation of sub-lexical codes. We found a significant effect of pseudo-homovisemy and interpret this finding within the DRC framework as the result of a mismatch between information from the indirect Grapheme to Viseme Conversion (GVC) route and the direct route (cf. Briesemeister et al., 2009; Ziegler et al., 2001). On encountering a pseudo-homoviseme, no entry in the orthographic lexicon reaches a sufficient level of activation which would lead to a timed-out 'no' response. However, activation from the GVC route that feeds into the visemic system and from there feeds into the visemic lexicon activates an entry. The greater activation caused by pseudo-homovisemes compared to their spelling controls would prompt the system to extend its time-out criterion resulting in longer response latencies to pseudo-homophones than spelling controls. However this account fails to explain base-word frequency effects, so (Ziegler et al., 2001) proposes the involvement of a spelling verification mechanism. High frequency words and more dominant spellings can be verified faster, which would match the empirical findings for hearing readers so far. Note that, even though we assume that the lexical decision task involves access to whole word representations and a response based on the orthographic form of the stimulus (as opposed to a phonological decision task such as used in Stenneken, et al., (2005)), sub-lexical information is automatically invoked during this process and probably affects response latency and accuracy.

We found no base word frequency effect for the pseudo-homovisemes amongst the deaf participants as has sometimes been found in hearing readers (e.g., Ziegler et al., 2001). The extremely high error rate for deaf participants on accepting low frequency words might offer a clue to an explanation. As shown in table 5, participants had an error rate of 21.48% for low frequency words. It is not implausible to assume that they have smaller German mental lexicons than the hearing. If so, it is possible that some of the low frequency pseudo-homoviseme base-words have no entries in their lexicons at all and therefore are treated as

regular non-words, diminishing the pseudo-homoviseme effect for the low base-word frequency stimuli.

In this study we only gathered evidence for the sub-lexical route, and thus only give an account of how and why PCA and speechreading could contribute to reading skill. Skilled speech readers may have strong visemic representations that can be mapped onto graphemes when learning to read, which could lead to the establishment of a well functioning GVC route in the mature reader. However, it is important to note that the DRC model of reading by deaf adults proposes that semantic, orthographic, lexical and sub-lexical information are also activated and interact with each other in a specific way when reading.

The role of the GVC route in reading by deaf adults is complicated by the fact that although on average we obtained a pseudo-homovisemy effect in our lexical decision task, an inspection of individual effects showed that six participants did not display an effect. Although our sample was too small to carry out statistical as well as correlation analyses, a visual inspection of the data showed that amongst the six participants who did not show an effect were both participants with high and low reading quotients. This suggests that not all deaf people phonologically recode while reading and that whether they do or not does not correlate with reading skill. This does not however necessarily mean that the DRC model's architecture is not applicable to all deaf readers. It would be possible to account for different strategies by different sub-groups through altering parameter settings in the model rather than proposing different architectures (see Coltheart et al. (2001, p. 209) regarding strategies and architectures) as we stated in the DRC model section above.

The finding that some participants did not show a pseudo-homovisemy effect is in line with the results of Mayberry et al.'s (2011) meta-analysis on PCA effects. Future studies comparing deaf readers who do and do not show effects of PCA and whether the difference can indeed be shown to stem from the use of different strategies for word recognition will be necessary for development of models of reading by deaf individuals.

As we stated above, we only gathered data relevant to the contribution of sub-lexical codes to reading skill amongst deaf individuals. However, below we also address how the DRC model of reading by deaf adults could account for the other skills shown to correlate with reading skill in the literature. Regarding the effect of Sign Language proficiency (Chamberlain & Mayberry, 2008): we speculate that exposure to Sign Language from early on in life could facilitate the building up of a large Sign lexicon and semantic system, which perhaps through a system like the one proposed in Hermans et al. (2008a) elaborated above, would in turn facilitate the acquisition of a large orthographic lexicon in the language that deaf individuals would be learning to read. We would account for the effect of vocabulary size (Kyle & Harris, 2010; Kyle and Harris, 2011) in the same manner; for the DRC model specifies the involvement of lexicons (orthographic and phonological) as well as grapheme-phoneme rules in reading. Furthermore, even though a semantic system is not yet implemented in the model computationally, this unit too plays a part in the online reading process.

In summary we propose a model that should be general enough to capture reading by all deaf individuals in principle. In fact, we propose that it is general enough to account for reading by both deaf and hearing individuals. As Coltheart et al. (2001, p. 246) describe, the

architecture of the DRC model is a proposal of what a mature well functioning reading system looks like. Mature meaning that the DRC model does not reflect the learning process of how such a system is arrived at, but states what the end product of the learning process is. However, the model can explain developmental dyslexias as a difficulty in acquiring any one component of the model. In a similar manner we propose that reading deficits of different types of deaf individuals can also be explained through a difficulty in acquiring any one component of the model. Whether this is the case in fact, rather than just possible in principle, will only be established through continued empirical research.

We also would like to address the predictions we make for outcomes for reading by deaf individuals in different orthographies; we expect the relationship between visemes and different orthographies to be almost equivalent to the relationship of phonemes to different orthographies. By almost equivalent we mean that for any language, the visemes will always map many to one to the phonemes, so deaf people of any country will always have access to fewer contrasts of a hearing person's language and perceive the lexicon of that language as more homophonous (homovisemic) compared to the hearing. Crucially however, the relationship between a viseme and a grapheme is the same as the relationship between a phoneme and a grapheme, even though there will always be less visemes than phonemes. Therefore the same problems that arise when accounting for the effects of phonology in non-alphabetic orthographies for hearing readers would hold for deaf readers. Perfetti, Liu, and Tan's (2005) work on East Asian orthographies illustrate the point. Their findings were that in non-alphabetic scripts hearing readers do show effects suggesting phonological mediation. It is our prediction that deaf readers of such orthographies would show the same phonological/viseme effects as the hearing readers based on deaf person's access to visemes. For Chinese deaf readers it may be that they have visemic-syllabic representations that serve the function of the acoustic-syllabic representations the hearing Chinese activate when reading Chinese characters. From this it would follow that future studies on how deaf individuals read, regardless of language and orthography, should always start with a specification of the viseme set available to the deaf readers. This is similar to Perfetti et al.'s (2005, p. 54) view on the role of phonology in different writing systems: "The difference between writing systems thus becomes not whether there are connections to phonology but rather what the relevant units are."

Perfetti et al. (2005) put forth a general theory for word reading across orthographies called the Lexical Constituency Model which states that word identities are comprised of linked semantic, orthographic and phonological constituents. We are in general agreement with the idea that word identification always involves these three types of information, and the DRC models of English (Coltheart et al., 2001) and German (Ziegler et al., 2000) and of reading by deaf adults reflects this.

In terms of the 'qualitative similarity hypothesis' (Paul & Lee, 2010) the proposed DRC model of reading by deaf adults assumes that deaf individuals use the same reading architecture as the hearing, the differences being a) the sub-lexical units in the GVC route are visemes, not phonemes, b) most deaf readers are bilingual in Spoken and Signed languages, so they have access to a bilingual lexicon which also affects reading.

Regarding point (a) this study is the first, to our knowledge, to specify possible sub-lexical units of deaf readers and to test their psychological validity in a lexical decision task using a standard RT-paradigm of the word recognition literature for hearing persons. The obtained pseudo-homovisemy effect suggests that sub-lexical units, in the form of visemes, could indeed be automatically accessed by some deaf individuals during reading. However, further work on identifying the exact units and assessing individual differences amongst deaf readers in their use, needs to be carried out. For example, we defined the viseme set based on visual features, not on tactile ones. It is plausible that deaf individuals have more visemic distinctions than presented in this inventory if tactile features are taken into consideration.

Results from recent studies (Hermans, Knoors, Ormel, & Verhoeven, 2008; Morford, et al., 2011) support point (b). Namely, there is evidence that both orthographic and Sign Language lexicons of deaf readers are activated during reading. The visemic lexicon proposed here would be a case of sub-lexical form overlap between the two lexicons for German/DGS bilinguals. As mentioned above, DGS makes robust use of German derived mouthings, so some DGS signs and German words overlap in form: i.e. they share common mouth shapes. That is, just as German and English have a sub-set of shared phonemes, we propose that mouthings constitute the sub-set of shared sub-lexical units between German and DGS.

In summary, our working model of single word reading by deaf adults attempts to describe the relationship between the various factors thought to contribute to reading skill amongst deaf individuals including: orthographic knowledge, sub-lexical and lexical representations of spoken languages, and a Sign Language lexicon as a dual route cascaded system. We have found some evidence supporting the existence of the GVC route amongst deaf individuals. All the components of the model, including the viseme set, require further elaboration and empirical testing.

2. Study Two

Facial expressions, emotions, and sign languages

Eeva A. Elliott*[1], Arthur M. Jacobs[1,2]

1 Department of Experimental and Neurocognitive Psychology, Freie Universität Berlin, Berlin, Germany.

2 Dahlem Institute for Neuroimaging of Emotion (D.I.N.E.), Berlin, Germany.

Abstract

Facial expressions are used by humans to convey various types of meaning in various contexts. The range of meanings spans basic possibly innate socio-emotional concepts such as 'surprise' to complex and culture specific concepts such as 'carelessly'. The range of contexts in which humans use facial expressions spans responses to events in the environment to particular linguistic constructions within sign languages. In this mini review we summarize findings on the use and acquisition of facial expressions by signers and present a unified account of the range of facial expressions used by referring to three dimensions on which facial expressions vary: semantic, compositional and iconic.

Keywords: sign language, facial expression, emotion

Introduction

Humans perceive facial expressions as conveying meaning, but where do they come from and what exactly do they mean? Based on observations of facial expressions typically associated with emotions Darwin (1904) hypothesized that they must have had some instrumental purpose in evolutionary history. For example, lifting the eyebrows might have helped our ancestors respond to unexpected environmental events by widening the visual field and therefore enabling them to see more. Even though their instrumental function may have been lost, the facial expression remains in humans as part of our biological endowment and therefore we still lift our eyebrows when something surprising happens in the environment whether seeing more is of any value or not. Following this tradition Ekman (Ekman, 1979; 1992) claimed that there is a set of facial expressions that are innate, and they mean that the person making that face is experiencing an emotion; i.e. brow raising means 'I feel surprised'. He also claimed that there are culturally acquired facial expressions used to modulate the innate emotional expressions, so-called display rules, and also others that are used for communication. Examples of the latter type are; a) an eyebrow flash used to mean 'hello', b) eyebrow movements during speech that emphasize certain words. According to this view, some facial expressions are 'read outs' of inner emotional states and the fact that they have a meaning to the observer is incidental, while others are used specifically for communication and are thus in some sense intentionally meaningful.

However, Fridlund (1997) claimed that there are no 'read outs' of inner emotional states; rather, what are usually regarded as emotional expressions evolved to communicate intentions. That is, raised eyebrows do not mean 'I am surprised', but might mean 'Something happened; I am going to find out what'. From this view all facial expressions evolved for communicative purposes.

The past 30 years of linguistic research on sign languages have revealed that there are facial expressions which are used together with manual signs and function as phonological features, morphemes, and syntactic/prosodic markers, for example brow raising marking conditional clauses (Dachkovsky & Sandler, 2009; Liddell, 1980). These facial expressions are clearly communicative in nature and they are used in combination with other meaningful movements (those of the hands).

In sum, there is evidence that facial expressions mean things ranging from possibly universal messages i.e. 'I am surprised'/ 'Something happened!' to culture specific learned meanings; i.e. 'hello', to culture specific meanings that can take part in larger composite structures with other meaningful elements, i.e. the conditional clause marker in sign languages.

How does one account for the range of meanings and uses of facial expressions? Following Wierzbicka (1999), we argue that facial expressions are semiotic units (form-meaning pairings) that can be analyzed with the same semantic methodology used to analyze words (see Wierzbicka (1996), for an account of her methodology). Two further working assumptions that we adopt from Wierzbicka (1999, p. 185) are: a) some facial configurations have identifiable context independent meanings; b) some facial expressions have a universal meaning which can be interpreted without reference to culture. Assumption (a) is also made

by Dachkovsky and Sandler (2009), although as far as we understand, they limit this claim to facial expressions used as prosodic units. Assumption (b) is shared by Ekman. Note that in general a strong argument can be made that some facial expressions are innate because they are also produced by congenitally blind persons (Matsumoto & Willingham, 2009), but determining their meaning is a matter of greater controversy.

To illustrate the controversy, we will briefly discuss the meaning of brow raise, as we use this facial expression as an example throughout this paper. Ekman (1992) proposes that it means 'I am surprised', but we adopt Wierzbicka's (1999, p. 205) suggestion that it means 'I want to know more (about this)'. We adopt Wierzbicka's interpretation for the following reasons: Wierzbicka points out that the term 'surprise' is not universal, it is part of Anglo language and culture. She suggests instead that the meanings of facial expressions can be better expressed using terms from the natural semantic metalanguage (Wierzbicka, 1996) for which she has some evidence of universality. Furthermore, it seems to us that part of the meaning of being surprised is, in fact 'wanting to know more about this [unexpected event that just occurred]', so the two interpretations are not completely incompatible. However we find Wierzbicka's definition more general with the power to cover the use of brow raise in relation to emotion and in sign languages, so it is this one that we adopt, acknowledging that currently there is no consensus on the matter.

As regards facial expressions in general, we propose that their differences and similarities can be explained in terms of three dimensions: semantic, iconic and compositional. These dimensions are derived from our first working assumption; that some facial expressions are semiotic units (form-meaning pairings). The semantic dimension refers to the meaning part of the semiotic unit, the iconicity dimension to the nature of the relationship between the form and the meaning, and compositionality to the way the semiotic unit can combine with other semiotic units to form complex semiotic structures. The semantic dimension spans meanings that are universal to those which are culture-specific. The iconic dimension spans the varying degrees in which facial expressions resemble their meaning. The compositionality dimension spans the degrees in which facial expressions readily combine with other semiotic units to form complex structures. A similar proposition to this has been made to account for the range of hand movements used by humans, covering the co-speech gestures of hearing individuals to signing by Deaf individuals (McNeill, 1992). In this mini-review we summarize evidence from acquisition of facial expressions by signers to support our view. We first present a brief overview of the role of the face in sign language structure. We then describe the proposed dimensions and the findings on acquisition of facial expressions by Deaf signers that support them, after which we come to a conclusion. Note that to the best of our knowledge currently there only exists acquisitional data on non-manuals for American Sign Language (ASL) and so the examples below all refer to ASL.

Sign languages and the role of the face
Sign languages are the naturally occurring linguistic systems that arise within a Deaf community and, like spoken languages, have phonological, lexical and syntactic levels of structure (Liddell, 2003; Sandler & Lillo-Martin, 2006). Cognitive and neurocognitive data provide evidence that signed and spoken languages are processed in a similar manner; for example, they show similar lexical access effects (Baus, Gutierrez-Sigut, Quer, & Carreiras,

2008; Carreiras, Gutierrez-Sigut, Baquero, & Corina, 2008) and they are supported by similar brain regions (Campbell, MacSweeney, & Waters, 2008).

Facial and head movements are used in sign languages at all levels of linguistic structure. At the phonological level some signs have an obligatory facial component in their citation form (Liddell, 1980; Woll, 2001). There are facial morphemes in ASL such as the adverbial 'th' meaning 'carelessly' (Crasborn, van der Kooij, Waters, Woll, & Mesch, 2008; McIntire & Reilly, 1988). Facial actions mark relative clauses, content questions and conditionals, amongst others, although there is some controversy whether these markings should be regarded as syntactic or prosodic cf. (Aarons, Bahan, Neidle, & Kegl, 1992; Baker-Shenk, 1983; Dachkovsky & Sandler, 2009; Liddell, 1980; Neidle, Kegl, Mac Laughlin, Bahan, & Lee, 2000; Nespor & Sandler, 1999; W. Sandler, 1999; Ronnie B. Wilbur, 2009; R. B. Wilbur & Patschke, 1999). Signers also use the face to gesture (Sandler, 2009). Below we describe how these uses of the face can be described in terms of three dimensions; semantic, compositional, and iconic with evidence from facial expression acquisition.

The semantic dimension

The semantic dimension refers to the meaning part of a semiotic unit. It has been proposed, especially for the meanings of facial expressions, that there are universal meanings and culture-specific meanings. Eyebrow raise is considered a unit with a universal meaning, and we adopt the suggestion that it means 'I want to know more (about this)'.

The brow raise appears to be used both with and without accompanying speech. Context can give it additional meaning beyond 'I want to know more (about this)', however we argue that even when more meaning is added by context it always retains its universal meaning. For example, hearing people may use brow raise while asking a yes-no question (Ekman, 1979), and when they are confronted with something unexpected in the environment. In both cases it still retains the meaning 'I want to know more (about this)' but in the former case it is related to the words in the question and in the latter to the event. Within sign languages too, brow raise is used in different contexts; it can mark yes-no questions and the antecedent of conditionals. Dachkovsky and Sandler (2009, p. 300) propose that despite these different linguistic contexts eyebrow raise has one meaning, namely "[…] the intermediate or intonational phrase marked by [brow raise] is to be followed by another phrase, produced either by the interlocutor or another." We find Dachkovsky and Sandler's interpretation compatible with that of 'I want to know more (about this)' or a similar formulation such as 'more information is coming'.

On the culture specific end of the semantic dimension lays, for example, the American Sign Language adverbial 'th' (carelessly), conveyed by sticking one's tongue out slightly between closed lips and tilting the head. In saying that 'carelessly' is a culture-specific concept, we mean that not all languages have labeled the complex set of behaviors and attitudes that make up the meaning of 'carelessly' with a word/sign. We do not mean, however, that the concept cannot be explained to someone whose language does not have a word for it.

The semantically universal facial expressions are logically the first to appear in acquisition. By 0:2 children are raising their brows in what Izard et al., (1995) call an expression of 'interest', but which we refer to as 'I want to know more (about this)'. Culture specific facial expressions such as the negating headshake appear at approximately 1:0 but they are not yet combined with signing (Anderson & Reilly, 1997; J. Reilly, 2005).

The iconicity dimension

We use the term iconicity to mean a form-meaning resemblance. Resemblance by its nature is a matter of degree. Some facial expressions resemble their meanings to a greater degree than others. The relation between the form brow raise and the meaning 'I want to know more (about this)' is iconic since raising one's brows to see more is a metaphorical icon (Taub, 2001), of wanting to know more. The adverbial 'th' (carelessly) also seems to be iconic since the slight tongue protrusion and head tilt could resemble the face of a person behaving carelessly. We do not have data on facial expressions used either by hearing or deaf people that are completely arbitrarily related to their meaning; however we think this is in principle possible because many semiotic units, especially in spoken language, do not appear to display any form-meaning resemblance. We propose the eye-wink, used in some Anglo cultures to mean 'I am not serious', as an example of a facial action arbitrarily related to a meaning.

In acquisition, since the universal expressions appear first, and since universal meanings would seem to necessarily have a form that is motivated by meaning (Wierzbicka, 1999 p. 213), therefore iconicity precedes arbitrariness. Even when signing children start combining expressions with signs at (1:6), the first types they use are emotion related facial expressions with emotion concept signs (McIntire & Reilly, 1988; Reilly, McIntire, & Bellugi, 1990b)

The compositionality dimension

Above we saw that brow raise can be used alone or in combination with other semiotic units such as words, i.e. it is compositional. In sign languages brow raise can be used together with manual signs (which are equivalent to spoken words). In spoken languages brow raise can also be used together with words however within sign languages there seem to be more restrictions on how brow raise is combined with signs/words. The first major difference is that in some sign languages brow raise is obligatory in yes-no questions (Dachkovsky & Sandler, 2009), while in spoken languages it is not. The second difference is that facial expressions that take part in composite sign structures seem to be more strictly timed to the onset and offset of signs/words compared to spoken languages (Veinberg & Wilbur, 1990). It would seem that there is an increase in the combinatorial options for facial expressions when shifting from use of the face with spoken language to use of the face as part of signing similar to that proposed for gesticulation and sign language in McNeill (1992).

Not all facial expressions have to appear in composite structures; however we are not aware of the existence of a facial expression that disallows combination in all cases. For example it seems that even emblematic facial expressions that usually stand alone, such as the 'hello' eyebrow flash mentioned above, could be used to replace words in a sentence. However, our point is that some facial expressions are more readily combined with other semiotic units than others, and that there are degrees in the regularity of composite structures, i.e. the

combination of brow raise with words in sign languages is more regular in occurrence and timing than in spoken languages.

The acquisition of full mastery of the combinatorial conventions of facial expressions in sign language appears to last at least seven years. The first combination of facial expressions with other semiotic units by signers happens at about 1:6. These facial actions appear to be phonological features. This is also when a manual sign for negation appears, but the child does not combine it with their headshake until two months later (1:8). At two years of age the first facial adverbials appear. At 2:5 children use facial expressions to depict other people's emotions and at 3:0 use the break in eye contact and mimicry of others to mark role-shift. 3:0 is also the age when children use the manual sign for 'if' but only at 5:0 do they start to use it with brow raise and only at 7:0 are they fully approximating adult production of conditionals (J. Reilly, 2005; Reilly, McIntire, & Bellugi, 1990a).

Conclusion

In terms of the three proposed dimensions, as children acquire facial expressions they move from innate universal concepts mapped onto iconic forms produced in holistic structures to culture-specific concepts, conventional form-meaning mappings, and increasingly complex composite structures. More data on facial expression acquisition in sign languages other than ASL, as well as data on the development and use of facial expressions in spoken language, will help to clarify what concepts and forms are universal (if any).

We find it important to note that our continua do not explain *how* children acquire facial expressions, rather they make a strong claim regarding *what* it is that children acquire: semiotic units and the knowledge of how to combine them into more complex semiotic units. This perspective contrasts with views claiming that emotion related facial expressions, facial expressions used by hearing people during conversation, and facial expressions used by signers while signing should be treated as distinct phenomena. We find it important to first accurately characterize the 'what' of facial expression acquisition as this necessarily constrains possible answers as to how humans acquire facial expressions.

3. Study Three

Phonological and Morphological Faces: Disgust Signs in German Sign Language

Eeva A. Elliott*[1], Arthur M. Jacobs[1,2]

1 Department of Experimental and Neurocognitive Psychology, Freie Universität Berlin, Berlin, Germany.

2 Dahlem Institute for Neuroimaging of Emotion (D.I.N.E.), Berlin, Germany.

Abstract

In this study we verify the observation that signs for emotion related concepts are articulated with the congruent facial expression for German Sign Language using a corpus. We propose an account for the function of this facial expression in the language that also accounts for the function of mouthings and other facial actions at the lexical level. Our data, taken from 20 signers in three different conditions, show that for the sign EKEL 'disgust' a facial expression occurred consistently, that it had scope in almost all cases over a single lexical item regardless of sentence type it occurred in, and that there was some degree of conventionalization in the form across signers as assessed using the Facial Action Coding System. We propose that facial actions at the lexical level be regarded as an additional layer of communication with both phonological and morphological properties. The relationship between this layer and manual lexical items is analogous in some ways to the gesture-word relationship, and the intonation-word relationship.

Keywords: Facial expressions, non-manual features, phonology, mouthings

Introduction

It has been observed that signs for emotion concepts in American Sign Language (ASL) such as RELIEVED (Liddell, 1980) or SAD (Reilly et al., 1990a) are produced with a facial expression that corresponds in meaning to the emotion concept, e.g.:

_____ frown

SAD

In the literature, this type of facial expression is often regarded as a phonological feature rather than a morpheme, since they occur on single lexical items but unlike facial adverbials they are not systematically used to modify the meaning of entire classes of signs. However, these facial expressions have not been well studied, for example to the best of our knowledge there are as yet no corpus studies that provide data on the frequency and distribution of such facial expressions, and so their linguistic function, i.e. whether they are best regarded as phonological features, morphemes, or something else, is not altogether clear.

Why should this phenomenon be studied? We think it should be studied for at least the following two reasons: (a) From a linguistic perspective, the use of an emotion related facial expression as a phonological feature violates the widely accepted definition of a phoneme, namely that phonemes are discrete meaningless elements. Emotion related facial expressions have a meaning and one can also argue that they are not discrete since they can display varying intensities of the emotion concept they convey. In order to know what the linguistic function of this type of facial expression is, their properties, such as distribution, frequency, and obligatoriness, need to be known. (b) From a psychological perspective, why certain facial expressions are often associated with emotions is still a controversial issue (Ekman, 2004; Izard, 2010; Russell & Fernandez-Dols, 1997; Wierzbicka, 1999). In particular the controversy focuses on whether facial expressions are indices of emotions at all, identifying what is cultural and what is innate, and on arriving at a scientific definition of emotion. For fully understanding the relationship between facial expression and emotion we think it is necessary to study all the ways in which emotion related facial expressions are used.

How wide spread is the use of emotion related facial expressions as part of the lexical specifications of signs? Informally it is reported that it occurs in other sign languages besides ASL, however we are only aware of one study that provides quantitative data on its use: Crasborn, van der Kooij, Waters, Woll, & Mesch (2008). They report that in their data set which includes Dutch, British and Swedish sign language, whole face expressions often with, in their words, 'an affective meaning' where the third most frequent facial action. However, they did not analyze this group further, as their study was concerned with actions of the mouth only.

Therefore, as a first step towards understanding the phenomenon we have gathered corpus data on emotion related facial expressions in German Sign Language (Deutsche Gebärdensprache: DGS). For the sake of brevity we refer to the emotion related facial expression that occurs on signs for emotion concepts as the emo-form (emotion form). The term emo-form does not refer to uses of facial expression in role-shift or in depiction of

speaker attitude, but only to facial expressions associated with lexical signs for emotion concepts. In order to accurately describe what the emo-form looks like we have used the Facial Action Coding System (FACS) developed by Ekman et al. (2002b). FACS refers only to muscle movements which has the benefit of allowing us to avoid the ambiguities that could arise from using verbal descriptions such as 'a sad face' or 'a frown'. FACS also makes it easy for other researchers to compare their data with ours.

In this paper we focus on just one DGS emotion concept sign: EKEL 'disgust'. In order to establish how best to classify the emo-form linguistically, whether as a phonological feature, morpheme, or something else, we ask the following questions:

1) Does an emo-form occur every time the manual component of EKEL 'disgust' is produced?

2) What is the scope of the emo-form when EKEL 'disgust' is produced in different sentence types?

3) Are the same muscles used across different signers to produce the EKEL 'disgust' emo-form?

The structure of the paper is as follows; firstly we provide an overview of the use of the face within sign languages, focusing on the lexical level. We then describe our methodology and present our results. Next we discuss our results in relation to other findings on the use of the face, and lastly provide a summary and conclusion.

Facial expressions in sign languages

Facial and head movements are used in sign languages at all levels of linguistic structure. At the phonological level some signs have a facial component in their citation form (Liddell, 1980; Woll, 2001). There are facial morphemes (Crasborn et al., 2008; Lewin & Schembri, 2011; Liddell, 1980; McIntire & Reilly, 1988) e.g. the ASL adverbial 'th' meaning 'carelessly'. Facial actions mark relative clauses, content questions and conditionals, amongst others, although there is some controversy whether these markings should be regarded as syntactic or prosodic (Aarons et al., 1992; Baker-Shenk, 1983; Dachkovsky & Sandler, 2009; Liddell, 1980; Neidle et al., 2000; Nespor & Sandler, 1999; Sandler, 1999; Veinberg & Wilbur, 1990; Wilbur, 2009). Signers also use the face to gesture (Wendy Sandler, 2009).

There is not much literature on facial actions at the phonological level and what does exist usually refers to the mouth, rather than the face as a whole (Boyes Braem & Sutton-Spence, 2001; Crasborn et al., 2008). Crasborn et al. (2008) created a typology of facial actions that occur at the lexical level (both morphemic and phonological facial actions) based on corpus data signed by six people from three different European sign languages (British, Dutch and Swedish). Below we report the relevant results of their study.

At this point a word on the notation conventions we use is necessary. Mouthings are written using the visemic transcription proposed in Elliott et al. (2012) and re-presented in table (3.1) below. It is similar to Keller's (2001) kinematic description of mouthings. This notation is fairly transparent as upper case Roman letters, familiar to any English reader, are used to

represent classes of phonemes that share visual appearance. For example the viseme /P/, described as 'lips compressed', maps onto the phonemes /p, b, m/. Readers can then know what the intended viseme in the transcription is, with minimal reference to the table, by attempting to articulate the letter. We transcribe the mouthing component to the right of the sign gloss with a '+' symbol, e.g.: BRUDER 'brother' + /P-UT-/.

Table 3.1 Visemic transcription of mouthings

Phoneme (CELEX notation)	Viseme	Description
b m p	P	Lips compressed
d n s t z	T	Lips slightly apart with tongue in contact with teeth
@ N g h k r x	-	Relaxed medium opening of mouth
l	L	Open mouth, tongue contacts alveolar ridge and drops
f v	F	Pouting of the lips while teeth stay together
I i j	I	Spreading of lips slightly open
E e	E	Medium opening of spread lips
a	A	Wide opening of mouth
& O Q o	O	Rounding of lips
U Y u y	U	Pouting of lips

Crasborn et al. (2008) found that between 50-80% of the manual signs across the three languages had a facial action component at the lexical level. They divided these facial actions into five categories: mouthings, adverbials, whole face actions, enacting mouth actions, and semantically empty mouth actions. The frequency ranking of each type is given in table (3.2) below:

Table 3.2 Frequency ranking of facial actions at lexical level from Crasborn et al. (2008)

Mouthings	Adverbials	Whole face	Enacting + Empty combined
39-57%	14-30%	16-20%	8-14%

The frequency scores above demonstrate that facial actions at the lexical level in sign languages are ubiquitous, suggesting they have an important function, but what is this function? Is it to add semantic content or is it rather to add phonological content for the purpose of making signs more perceptually distinct?

The only type of facial action that did not appear to have independent semantic content was the 'semantically empty type', comparable to Woll's (2001) 'echo-phonology'. An example of this type from British Sign Language is SUCCEED + /PA/. In this sign the hands start in contact and move apart and simultaneously the lips start in contact and move apart. Since empty-types are meaningless they can easily be treated as phonological features given the common theoretical assumption that the phonological level consists of a finite set of discrete, meaningless units. However, this type comprised the smallest category. It is far more common for facial actions in sign language to have semantic content independent of what the hands convey.

For example, mouthings seem to inherit the meaning of the spoken language word they are derived from. They can behave like phonological features when they disambiguate signs that are manually identical. For instance, in DGS BRUDER 'brother' and SCHWESTER 'sister' are both symmetrical bi-manual signs with a G-handshape, and contact between the two hands. The only difference between them is in the mouthing /P-UT-/ and /SFETT-/. Thus BRUDER and SCHWESTER constitute a minimal pair in DGS differing in their mouthing feature. However, mouthings can also behave morphemically when they form compound signs with a manual component e.g., EAT+/P-ET/ meaning 'eating bread' (Crasborn et al. 2008). More often though, it seems to be the case that, mouthings have no disambiguating function and that their semantic content is redundant. For example the sign WURM 'worm' occurred with the mouthing /FU-P/ in our corpus. The sign WURM 'worm' to the best of our knowledge, does not form a minimal pair with some other sign in DGS, and the semantic content of the manual and facial component appear to be identical, making the function of mouthings in these cases difficult to explain.

Adverbials appear to only function as morphemes, while enacting actions and whole face actions appear to have the mixed morphological/phonological/unexplained profile of mouthings. An example from British Sign Language of an enacting action used as a phonological feature is a chewing mouth action occurring with the manual part of the sign CHEWING. An example of an enacting action used morphologically is a shouting mouth action made with the manual sign RUN meaning 'to run while shouting'. Whole face actions are like enacting actions except that they are not just limited to actions of the mouth. Besides reporting that they were the third most frequent mouth action in their data, the authors of the cited study did not consider them further as they limited their study to mouth actions with no other facial muscle involvement.

The fact that, mouthings behave like phonological features in some cases, like morphemes in others, and are seemingly redundant in others, as well as the fact that they are borrowed from spoken languages have led to large disagreements on how to classify them linguistically. One view is that they are not linguistic elements at all (Hohenberger & Happ, 2001) another view is that they are linguistic elements of spoken language that are simultaneously used with sign

(Ebbinghaus & Hessmann, 2001) while others treat some of them as borrowings (Vogt-Svendson, 2001). What we regard as the most important finding of the Crasborn et al. (2008) study, is that not only mouthings have a mixed morphological/phonological/unexplained profile. Enacting actions behave this way too; i.e. in some cases they appear to be part of the phonological form of the word, e.g. CHEWING+ 'chew mouth' above. In other cases they behave like morphemes and create compound signs, e.g. RUN+ 'shouting mouth' above.

It would seem then that the apparent semantic redundancy and the flexibility between phonological and morphological function is a more general property of facial features than just a particular problem of mouthings. Furthermore, these properties can also be seen in manual features: The manual parameters of handshape, location, and movement, regarded as the discrete meaningless units of sign language phonology, behave like independently meaningful morphemes in classifier constructions (Sandler, 2009, p. 261) and the distribution of certain hand-shapes within the lexicon has been shown to be better explained by their meaning (i.e. their morphological potential) than their form (Fuks & Tobin, 2008). We address the significance of these facts in further detail in the discussion section below.

Regarding the domain of facial actions at the lexical level, Crasborn et al. (2008) found that for 8-13% of mouthing tokens and 0-20% of semantically empty tokens the facial action spread to another sign. Typically this would be a pointing sign, such as a pronoun or index. However there were a few cases in which the facial action spread over up to three signs. This suggests that their domain might be the prosodic word or some other constituent larger than the lexical sign.

In sum, the role of the face at the phonological level of sign languages has not been intensively studied, and in the studies that do exist, the mouth is usually treated to the exclusion of other facial muscle actions. A particular class of mouth actions, namely mouthings, seems to sometimes behave like phonemes, sometimes like morphemes, but most often this class seems redundant. This flexibility between phonological and morphological function is also found for enacting actions and manual features. Having presented the background to our study we continue below with the methods and results of our investigation of a particular whole face action in DGS; the emo-form occurring with the sign EKEL 'disgust'.

Methods

The goal of our current study is to provide quantitative data on the occurrence and distribution of emotion related facial expressions used as linguistic elements at the lexical level, i.e. emo-forms. We attempt to achieve this goal by answering the following three questions based on our corpus data.

1) Does the emo-form occur every time the manual component of EKEL 'disgust' is produced?

2) What is the scope of the emo-form when EKEL 'disgust' is produced in different sentence types?

3) Are the same muscles used across different signers to form the EKEL 'disgust' emo-form?

Structure of corpus

Following many suggestions in Johnston & Schembri (2006) we created our corpus in the following manner: The corpus consists of three parts. In the first part participants were told that they will be shown sentences in written German. Following the practice in Dachkovsky & Sandler (2009) when using a translation task participants were asked to look at the sentence and to consider for a moment how they would translate it into DGS. They were told to try not to be influenced by the structure of German or Manually Coded German. The second part of the corpus consists of a free speech section. Participants were asked their opinion on a question regarding DGS and their response was recorded. The third part of the corpus consists of single words. Participants were shown two lists of emotion related words in German, and were asked to translate them into DGS. Three deaf native speakers of DGS transcribed the first two parts of the corpus. In this study we only look at a subset of the corpus, namely elicited sentences and single words for the emotion concept sign EKEL 'disgust'. The other sections of the corpus will not be further discussed here.

Participants

There were 20 Participants, (nine male, average age 26.45 Max=39, Min=23). 15 reported being native speakers of DGS. Eight acquired DGS from birth, seven were early acquirers (between ages 1-5), four acquired DGS after the age of five (Max=21). Data on age of acquisition is missing for one participant. Nine participants had at least one deaf parent. They were recruited by two Deaf native DGS speakers through personal contacts and advertisements. They received monetary compensation for their time.

Procedure

A native DGS speaker carried out the interviews for the corpus. Participants were interviewed at their homes or at the Humboldt University's Deaf Studies Department's studio. Participants were seated in front of a camera and received an explanation of the procedure.

The eliciting materials for EKEL 'disgust' signs were two sentences in written German as well as a single written word:

a. Ich bin angeekelt von Würmen.

I am disgusted by worms.

b. Mein Freund hat gesagt dass er angeekelt von Würmen ist.

My friend said that he is disgusted by worms.

c. Ekel

Disgust

For each eliciting condition EKEL 'disgust' was analyzed with FACS (Ekman et al., 2002b). FACS is a system with which to code all visibly detectable movements of the face based on the facial muscles which cause this movement. Each facial muscle, or in some cases a group

of muscles, is called an action unit and assigned a number. For example the raising of the lip corners, done primarily by the zygomaticus major muscle is assigned the action unit 12.

Since we are looking for facial actions at the lexical level we analyzed the time window between onset and offset of the sign EKEL 'disgust'. Onset was defined as the first frame in which the hands are detected to move into the preparation phase and offset as the last frame in which the hands complete the retraction phase of the sign. Action units that were already present before onset were not coded unless they gained in intensity. Action units that had their onset within the time window analyzed but reached their apex after offset were likewise not coded. This was to avoid confounding action units which belong to higher prosodic domains with action units that are part of the lexical sign. So for example if the entire sentence is signed with a disgust expression to depict the attitude of the speaker, or as part of role-shift, but the time window of the sign EKEL 'disgust' has no additional specific action units we coded zero action units. We chose to analyze signs for 'disgust' as the action units associated with this emotion concept according to Ekman et al. (2002a) largely involve the mouth and not the upper face. Since the upper face is known to have functions at the prosodic level in signed languages, choosing signs that would primarily engage the mouth would make it easier to disentangle actions occurring at the lexical level from those occurring at higher levels.

Results

Reliability of coding

The agreement ratio between the two coders on a subset of the data (20 videos, 32% of the data) was 0.6 using the agreement formula provided in the FACS manual. As this was rather low the two coders arbitrated their scores. The main source of disagreement was between AU26 (jaw drop) vs. AU27 (mouth stretch), AU15 (lip corner depressor) vs. AU20 (lip stretch) and the presence or absence of AU17 (chin raiser). The judgment of the more experienced coder was accepted in most cases and the agreement score after rescoring by the less experienced coder was 0.87. The remaining videos were then recoded by one of the coders in accordance with results of the arbitration.

Tokens in corpus

For our three conditions across 20 participants we elicited a total of 63 EKEL 'disgust' tokens. The reason that there are more tokens than eliciting conditions multiplied by participants (3*20=60) is that in 5 trials the elicited sentence construction consisted of repetition of the sign EKEL 'disgust' and there were two trials in which participants did not respond. The 63 tokens were categorized into 12 different types, i.e. different signs which are synonyms or dialectical variants of EKEL 'disgust'.

Table (3.3) below shows the 12 unique sign types along with the number of tokens per sign, and figure (3.1) shows an example of a participant signing EKEL 'disgust' in each condition.

Table 3.3 List of sign types and their token numbers

Sign Type	Description			Tokens
	Handshape	**Location**	**Movement**	
1	5-handshape	thumb contacts chin	moves outwards	11
2	5-handshape bi-manual	hands held face level palm outwards	local movement	11
3	5-handshape	hand contacts throat	moves towards throat	10
4	I-handshape	neutral signing space	sideways movement away from body	7
5	5-handshape	contacts non-dominant hand	moves towards shoulder	5
6	B-handshape palm inwards	contacts chin	repeated outward movement	4
7	5-handshape bi-manual	at stomach level	upward movement	4
8	5-Handshape bi-manual palm upwards	mouth area	outward movement	3
9	F-handshape	neutral signing space	local movement	3
10	5-handshape with middle finger bent	contacts neck	inward movement	2
11	5-handshape with middle finger bent	neutral signing space	downward movement	2
12	A-handshape with extended thumb	thumb contacts chin	outward movement	1
			Total:	63

Figure 3.1 Production of EKEL in three different conditions: direct speech, reported speech, and as single word

We did not expect to find such a rich DGS vocabulary for the concept 'ekel/disgust'. In order to determine how many of the 12 types where synonyms for the concept 'disgust' and how many were dialectical variants, we consulted a Deaf native DGS speaker with a background in Deaf Studies. We asked our consultant in which region of Germany is the sign used, how frequently he thinks it is used on a scale of 1-5 with 5 being 'very frequent', and how would he describe its meaning. This analysis is of course only preliminary and requires support from future lexicographic and corpus studies in DGS. The results of this analysis are given in table (3.4) below.

Table 3.4 List of sign types and their meaning

Type	Region	Subjective Frequency	Description of Meaning
1	Across Germany	4	Used to describe dislike of a task or thing. For example dislike of a job.
2	Across Germany	3	Used to mean that something is unpleasant to see, for example spiders or worms.
3	Berlin	4	Used mainly to describe dislike of a food, or to say that a person does not look good.
4	Across Germany	4	It has its origin in the German interjection 'iiii' ('ew/yuck'). Used to describe dislike of something, but not used in reference to humans.
5	Across Germany	4-5	Usually transcribed as *gänsehaut* 'goose flesh'. Used to describe being cold, being frightened, and being disgusted. Often associated with eating or touching something unpleasant.
6	Across Germany	3	A slightly more polite way to say one does not like something, for example food.
7	Across	2	Used to say one dislikes a person or a food. Usually

	Germany		transcribed as *schlecht* 'nausea', however it does not mean physical nausea, there is another sign in DGS for physical nausea.
8	Hamburg	-	Is used to describe dislike of persons or things. Often transcribed as *erbrechen* 'vomit', but it does not mean to physically vomit. There is another DGS sign for physical vomiting.
9	Saxony	2	It describes the sensation of disgust one would have touching something unpleasant.
10	Across Germany	3	Used to describe not liking something, but in a more factual and less emotionally involved manner.
11	? Used by youth	3	Usually transcribed as *hass* 'hate'. It is used for example to say one dislikes a particular food.
12	Cologne	2	It is used to say of a person or a thing that they look bad.

In sum, the above descriptions show that DGS has at least seven 'disgust' related concepts used across Germany and five that appear to be region specific. The various concepts appear to distinguish between whether a sense of disgust is due more to seeing, touching or tasting, and also whether the referent is human or non human.

In order to answer our first question, does an emo-form occur every time the manual component of EKEL 'disgust' is produced, we did the following analyses:

For 62/63 tokens at least one action unit that was unique to the time window of EKEL 'disgust' occurred. The average amount of action units per token was 5.01 (SD=2.18, Mode=3, Min=1, Max=9). The movements made were strong and clear; the average intensity of an action unit on a scale of 1-5 with 5 meaning maximal possible intensity was 3.55 (SD 0.3, Min=3, Max=4). In the single case where there were no action units unique to the time window of the lexical item, we found that they spread beyond the lexical item to include the immediately preceding first person pronoun. The mean duration in milliseconds of the time window we analyzed with FACS (equivalent to the length of the sign) was 827.32 (SD 287.51, Min 351, Max 1769). The variation in length of EKEL 'disgust' is due mainly to sentence position. If the sign was sentence final it had a much longer retraction phase than in sentence medial position.

The action units started at onset or in 4/62 cases at the stroke phase of EKEL 'disgust' and faded with the retraction. It was clear that the face and the mouth in particular, were engaged in rapid movements timed to the segmental actions of the hands throughout the sentences and not just on EKEL 'disgust'. Average mouthing rate, calculated as number of signs containing a mouthing divided by total signs was 0.41 (SD, 0.17). That means that for almost every

second sign, the mouth was engaged in our data set. This mouthing rate for DGS is similar to that reported in Ebbinghaus & Hessmann (2001).

In three cases the facial action that occurred with EKEL 'disgust' was a mouthing or mouth gesture, coded as AU50, with no other detectable movements. In nine cases there were both mouthings and additional facial actions. The average number of additional action units in these cases was 2.2 (mode = 3), and the two most frequent action units in these cases were AU7 'lids tight' (4/12 cases) and AU9 'nose wrinkle' (4/12 cases). There were two different mouthings that occurred; /SLE-T/ and /E-EL/ derived from the German 'schlecht' (nausea) and 'ekel' (disgust) respectively. There was one case of the DGS mouth gesture 'pff'.

In addition to the data above signing informants reported that the facial component for emotion related words is usually obligatory. They stated that producing the manual part of EKEL 'disgust' without the facial component is marked as formal speech.

From above we see that facial movements unique to the time window of EKEL 'disgust' occurred in all but one case. However, can these facial movements, excluding mouthings, be reasonably said to comprise a facial expression that can be interpreted as a depiction of the concept 'disgust', i.e. was it an emo-form as we expected rather than a case of echo-phonology, or something else? To answer this question we provide a description of the particular action units that occurred in our data.

A total of 18 different action units were detected in the analyzed tokens and there was no one action unit that occurred in 100 percent of the data. Table (3.5) below gives the ten most frequent action units in the data.

Table 3.5 Frequency of action unit occurrence for the emo-form disgust

Action Unit		Frequency of occurrence (%)
AU25	lips part	74
AU19	tongue show	52
AU26	jaw drop	40
AU15	lip corner depressor	35
AU7	lids tight	32
AU17	chin raiser	29
AU10	upper lip raiser	27
AU20	lip stretch	24
AU4	brow lowerer	22
AU50	speech (mouthing)	21

Most typically than, it can be seen that signers opened their mouths and showed their tongues when signing EKEL 'disgust'. This can plausibly be interpreted as an iconic depiction of disgust, i.e. an action to remove something from one's mouth. Lip raising (AU10) and nose wrinkling (AU9), which according to Ekman et al. (2002a) are the core of the prototypical 'disgust' related facial expression also occurred in our data, but not particularly frequently (AU10 in 27% of the data and in AU9<21%). The other action units above can all also plausibly be interpreted as expressions signifying displeasure (e.g. down turned mouth corners (AU15) lowered brows (AU4)), and in no case was there a smile restricted to the analyzed time window. However, in 6 cases a smile did have onset during the sign analyzed, but it remained on the face well after offset of the sentence; 3864ms on average. This smile seemed to be directed at the interviewer and to express the amusement of the participant with the task.

The answer to our first question then is no, a detectable emo-form did not occur with every instance of EKEL 'disgust' in our data set. In one case there were facial actions but they spread over EKEL 'disgust' and a pronoun, and in 4/63 cases there was a mouthing with no additional facial movements. However, in the majority of cases there was an emo-form, and we also found that mouthing can co-occur with the emo-form, this happened in 9/63 cases. Given that in the four cases were there was no detectable emo-form a mouthing occurred, it is possible that the signer did in fact make a disgust related facial expression but it was masked by the movements of the mouthing. Our tentative conclusion then based on our corpus data is that the emo-form is an obligatory feature of the various signs for EKEL 'disgust'.

In answer to question (2), what is the scope of the facial action, in all but one case the facial actions occurred within the time window of the lexical sign, however in one case it spread to the immediately preceding first person pronoun. This might suggest that the domain of facial action is the prosodic word rather than the lexical word however; we do not at present have reliable diagnostic criteria for determining the prosodic word in DGS. It does not seem to be the case that the first person pronoun was cliticized onto EKEL 'disgust' since there was no reduction in form of the pronoun comparable to that described in Sandler (1999). This issue remains to be addressed by future research.

Our data so far shows that in most cases EKEL 'disgust' was accompanied by an emo-form however it was instantiated differently in every case which brings us to our last question, (3) is the emo-form conventionalized?

When examining total tokens as shown in table 4 above, we found high variability in the choice of action units used to create the emo-form for EKEL 'disgust'. The range of action units used totaled 18 but for each individual token the average number of action units used was a small subset within this range; on average 5 (SD 2.18) action units. No strong pattern in muscle configuration was apparent when looking at all tokens. The only two action units to occur in over 50% of the cases were lip opening (AU25) and tongue show (AU19). Our conclusion from this data then is that the emo-form is partially conventionalized in its appearance.

Since we did unexpectedly elicit 12 synonyms for EKEL 'disgust', it is of course possible that each synonym is associated with a particular muscular configuration. We do not have enough data points for each type to carry out analyses that could establish this however.

In summary, when the sign EKEL 'disgust' is produced it is highly likely that it will occur with a facial expression depicting disgust, that this facial expression is rather brief lasting about 800ms (i.e. spanning the length of the lexical sign), and that there are variations in which muscles are used during the facial expression but most typically it consists of opening of the mouth and tongue show. What can this data tell us about the function of the emo-form? We attempt to answer this in the discussion section below.

Discussion

According to our data the emo-form has scope only over lexical items, it appears almost every time an emotion related lexical item is signed, and signers state that the production of emotion related signs must be done with the corresponding facial expression. All this suggests that the emo-form is a part of the phonological form of the lexical item EKEL 'disgust'. This use of a facial expression seems unique to sign languages, for we do not know of spoken languages in which speakers make a facial expression timed specifically to the onset and offset of words such as 'disgust' or in which speakers report that 'disgust' needs to be articulated with the corresponding facial expression[1].

However by stating that the emo-form is phonological, one runs into the same problems one has in stating that mouthings are phonological. One of these problems is apparent redundancy. The manual component of EKEL 'disgust' appears to have sufficient phonological information to make it distinct from other items in the DGS lexicon. Why then do signers expend extra energy in using additional articulators for the sign EKEL 'disgust' when the manual component would seem to suffice? If we accept Zipf's principle of least effort (i Cancho & Sole, 2003; Tobin, 1997; Zipf, [1949] 2012), namely that a human will not put more effort into articulating a word than is necessary for enabling the receiver to decode it, we would have to conclude that the emo-form is not redundant and must have some benefit to the receiver of the signal that justifies the extra effort on the part of the sender. This could be tested in future psycholinguistic experiments for example by measuring whether sign recognition is facilitated for signs with a facial component compared to signs with no facial component.

One could also try to account for the emo-form semantically instead of phonologically, on the grounds that the emo-form standing alone is already a semiotic (meaning bearing) unit. However, as with mouthings, here too one runs into a redundancy problem. The emo-form does not seem to function like a morpheme in the sense that it does not modify the meaning of EKEL 'disgust' rather it seems to repeat it. Nevertheless, as stated above, mouthings, and enacting facial actions do have the capability of taking on a morphological function by

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[1] English speakers may use a facial expression depicting disgust when using the word 'disgust' in a sentence, but this expression does not seem to be timed to the onset and offset of 'disgust' but rather has scope over a large portion of the clause, and the expression would function to depict the attitude of the speaker. Signers also make such use of facial expression to convey speaker attitude (Liddell, 1980), but our point is that this is different from emo-form function.

forming compounds with manual lexical items that are not semantically identical and in this way they resemble facial adverbials. As yet, we do not have empirical evidence that emo-forms can act as morphemes, but we think it is likely that such evidence will be found.

In sum so far, we propose that the emo-form has both a phonological and a semantic function, and that its redundancy is only apparent, otherwise it would not appear in the language following Zipf's principle of least effort. Our tentative explanation for their function is that they are of benefit to the receiver of the signal in the cases in which they repeat semantic information, and they function as morphemes in the cases where they add semantic information. This hypothesis can be tested in future psycholinguistic experiments. Furthermore we propose that emo-forms, mouthings, enacting actions, facial adverbials, and semantically empty actions make up one class of units based on their common profiles. Their differences can be accounted for in terms of their origins and their location on a continuum of function: emo-forms are adopted from emotion related facial expressions, mouthings from the ambient spoken language, enacting actions and facial adverbials from mimetic enactments, and empty actions from imitation of hand movements. These types form a continuum between purely phonological function and purely morphological function.

These units seem to form a layer that is somewhat independent of the manual stream, but complementary to it. A relationship between two independent but related streams of information is also found between gesture and words, and intonation and words. The relationship between gesture/words and intonation/words is not reducible to the relationship between the articulators hands and face, for it has been shown that words can be articulated either by vocal muscles or the hands (Stokoe, 1960), and gesture can be articulated either by hands or facial muscles (Sandler, 2009). Similarly, we think that the relationship between the lexically timed facial action layer and signs cannot be accounted for by direct reference to articulators, but by reference to the simultaneous production of information types that can potentially be produced by any articulator. That is, we propose that the layer in which emo-forms, mouthings, enacting facial actions, facial adverbials, and empty actions occur be considered a system of information used in parallel with gesture, intonation, and, lexical items. We explain this proposition in detail below.

Multiple layers of information in communication

Ebbinghaus & Hessmann (2001) proposed that mouthings constitute a sign type that can be used together with manual signs, but they are not themselves a component of the manual sign. They state that the multi-dimensionality of sign languages allows this unique coordination of heterogeneous sign types possible. We are in general agreement with the idea that in the case of mouthings two semiotic units that are to some degree independent of each other are being used in a coordinated manner and we extend this to emo-forms and enacting actions as well. However we disagree that the coordination of heterogeneous sign types is unique to sign languages. We think that there is ample evidence that multi-dimensionality is a general property of human languages, spoken and signed, and that the coordination of heterogeneous sign types is ubiquitous.

We use the term multi-dimensional to mean that two or more types of related information are simultaneously being transmitted and multi-modal to mean that one or more physically independent sets of articulators are being used to send a message that can be detected by one or more sensory modalities. The fact that the act of human communication is multi-dimensional and multi-modal; containing information encoded in gestures (Dachkovsky & Sandler, 2009; Kelly, Ozyurek, & Maris, 2010; McNeill, 1992; Mueller & Posner, 2002), information encoded in intonational units (Dachkovsky & Sandler, 2009; Ladd, 1996; Nespor & Sandler, 1999; Sandler, 1999), information encoded in facial expressions (Eibl-Eibesfeldt, 1975; Ekman, 2004; Fridlund, 1997; Wierzbicka, 1999), used together with the information encoded in lexical items and syntactic constructions is receiving increasing documentation. Below we describe these information types, what is known about their properties, and how tightly they seem to be connected to lexical items.

Information encoded in co-speech gestures

According to McNeill (1992) the type of information typically encoded on co-speech gestures is visual imagistic information such as direction, path, manner, size, and shape, e.g: moving the hands upwards while saying "he climbs up the pipe".

Gestures as semiotic units have different properties to that of lexical items. Amongst other properties proposed in McNeill (1992) they are global and synthetic i.e. the meanings of the parts are determined by the whole and different meaning segments are synthesized into a single gesture. This is in contrast to the duality of patterning (the possibility to decompose a semiotic unit into a set of finite discrete meaningless units) seen in lexical items. Gestures, unlike words, do not combine into larger structures; they are non-combinatoric. There are also no standards of well formedness for a particular gesture. Each individual can produce the form of the gesture as she wishes i.e., they are idiosyncratic.

Gestures co-occur with lexical items in the following way: there is usually one gesture per clause. They are timed to the onset of particular lexical items. They add complementary information to that encoded in the lexical item. The preparation phase (hands moving into position) of a gesture anticipates speech, and then synchronizes with it during the stroke (the execution of the gesture). The stroke is timed to end at or before, but not after, the peak syllable.

Information encoded in intonational units

Intonational units following Ladd's (1996) definition encode post lexical information, namely information about sentence type, speech act, and information structure such as topic and focus. This type of information is mainly carried by suprasegmental features such as high tones and low tones in spoken languages and mainly by facial features in some signed languages (Dachkovsky & Sandler 2009) however the face may also play a role in spoken language prosody (Krahmer & Swerts, 2009).

The properties of intonational units, if one accepts a componential model as proposed for example in Dachkovsky & Sandler (2009) and Bartels (1999), are as follows: there exists a finite set of intonational primitives, and these primitives encode a meaning, e.g. brow raise

means 'more information is coming', and these units can combine with one another according to rules to create a complex meaningful structure. So like gestures, the primitives are semiotic units that do not have the property of duality of patterning, but unlike gestures the units can combine with each other to form complex structures.

Intonational units are timed to word onsets and offsets and their scope seems to be determined by reference to the relevant level in the prosodic hierarchy; in the case of intonational units this would be the intonational phrase. They are also conventionalized, meaning that all members of the speech community use the same form-meaning pairings.

Information related to emotions or intentions

The type of information I wish to address in this subsection is that related to emotion and intention. Before discussing the properties of this information type we wish to clarify our terminology. In ordinary English it is natural say that one can express emotions through gesture and intonation. This is so because the ordinary English terms highlight the particular articulators most often used in gesture and intonation namely hands and voice. It is true that emotion/intention can be signaled by the hands and voice, but crucially it is a different information type to that defined for gesture (imagistic information on size, shape, etc.) and intonation (post lexical information). We use the terms gesture and intonation in the technical senses defined above, so by our definition emotion/intention cannot be conveyed in gesture or intonation. The importance of not confounding information type with the articulator set prototypically associated with it will be further addressed below.

This information type, following Wierzbicka's (1999) analysis, is inherently in first person and present tense orientation. This type of information appears early in acquisition, before speech and gesture (Izard et al., 1995). The primitives are semiotic units that do not display duality of patterning. Although several different emotion/intention expressions may be simultaneously transmitted, i.e. raised eyebrows and a smile meaning something like 'I want to know more and I feel good', we are not aware of evidence that they combine with each other in hierarchical structures. So for the present we assume they are non-combinatoric.

This type of information is usually associated with the face, but can also be encoded in the voice (Pittam & Scherer, 1993) and the hands (Reilly, McIntire, & Seago, 1992). There is cross cultural evidence (Ekman, 1972) and evidence from the congenitally blind (Matsumoto & Willingham, 2009) suggesting that some of the facial expressions for this information type are innate and universal. The form of these units then is the same across the community of users, not because of social convention, but due to innateness. These types of units do not seem to align with lexical items as seen in our data on smiles above and in Baker-Shenk (1983) for example.

Summary of information types

The main points that we wished to make by describing the various information types conveyed during face-to-face communication by humans is that multi-dimensionality and multi-modality is a property of both signed and spoken languages and that information type is

not necessarily bound to one set of articulators[2]. The Information types described are summarized in table (3.6) below.

Table 3.6 Information type layers and properties

Label	Information Type	Structural Properties	Relation to lexical items	Possible Articulators
Gesture	Imagistic information about direction, path, manner, size, and shape	No duality of patterning Non-combinatoric Idiosyncratic	Timed to the peak syllable of lexical items.	Hands Face
Intonation	Sentence type, speech act, topic and focus	No duality of patterning Combinatoric Conventionalized	Timed to onsets and offsets of lexical items in an intonational phrase	Vocal folds Face
Emotion/ intention signals	Emotions and intentions in the first person present tense orientation	No duality of patterning Non-combinatoric Possibly Innate	Not timed to lexical items	Face Vocal folds Hands

The division and characterization of the information types above reflects our understanding of the current state of research in the respective fields, however we by no means claim that this is a comprehensive list or description of information types in communication. Additionally, we are not suggesting that the categorization we provide is discrete. In fact McNeill (1992) proposes that gesture and language are on a continuum. Gestures can lose some of their properties and gain others and become lexical items in sign languages. This is an important point for explaining the emo-form, enacting facial actions, mouthings, facial adverbials, and empty actions. The emo-form seems to originate in emotion/intention signals, but it appears to lose its first person present tense orientation when it is used with lexical items in DGS.

A potential problem that arises from our proposed typology is that equivalent information can be encoded by each layer, so are we justified in defining our layers on the basis of information type? For example, information about size, shape, path, manner, etc. can also be encoded lexically by saying "he climbed up the long pipe in a hurried zigzag fashion".

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[2] Whether and which of the semiotic systems we describe should be regarded as linguistic or extra linguistic is not an important distinction for the purposes of this paper. We wish only to claim that multiple systems are used together and that the systems seem to have some shared and some unshared properties.

Emotion/intention can similarly be expressed lexically by saying "I feel bad now", and so on. It appears to us however that the three systems described above reflect an optimization for the transmission of a particular type of information. One can plausibly argue that the most efficient, i.e. quickest, way to transmit information about size, shape, manner, is simply to show it to the receiver by creating a visual analog of the size, shape etc. one has in mind rather than describing it in words. In turn, the most efficient way to create a visual analog would seem to be by using the hands, which would explain way gesturing by hearing persons is done by the hands. However, humans appear flexible enough that when the hands are occupied with signing, the face can take over gesturing.

The parallel lexicon layer

The question then remains what type of information is transmitted in the layer in which emo-forms, enacting actions, mouthings, facial adverbials, and empty types occur? It would seem that the information type of this level is very much like that of lexical items. That is lexical items can potentially encode any kind of concept, even though some kinds of information (like size & shape) are more efficiently encoded through other means. Mouthings certainly have the potential to encode any kind of concept, as they are derived from ambient spoken language words, while enacting actions and emo-forms encode concepts from the domains of action and emotion/intention respectively. However, unlike lexical items, it does not seem to be the case that within this layer items combine with each other into complex structures. Our tentative proposal then is that this layer be considered a parallel lexicon to the manual lexicon. Given that this parallel lexicon usually repeats the semantic content of the manual sign it co-occurs with we think its primary function is phonological, i.e. to create perceptually distinct signs, although it can also take on morphological functions as the cases of mouthing-manual compounds and fully fledged facial adverbials attest.

A final issue we address before concluding is that of simultaneity of production. In our data we saw that mouthings and emo-forms as well as smiles and emo-forms could co-occur. In terms of our parallel lexicon proposal, this would mean that within a layer there can be stacking of information as well as between layers. Note that this also occurs in the intonational system; according to Dachkovsky & Sandler (2009) 'brow raise' and 'squint' can be simultaneously produced. The question arises, is there an upper limit to the amount of information a human can stack during communication?

From the perspective of the sender the upper limit would seem to be the availability of articulators that can be independently manipulated and perhaps also the transmission rate of the type of information being sent on that articulator. For example in the cases of the co-occurrence of mouthing with the 'disgust' emo-form, and brow raise with squint, each item could use different muscles within the facial set, so there was no competition for resources. However, even in the case when the exact same muscle is required for two different information types, simultaneous production still seems possible and can be realized either through greater intensity of muscle use (de Vos, van der Kooij, & Crasborn, 2009) or by one movement being held longer than the other, as in the case of the smiles in our data which started during the articulation of the 'disgust' emo form, but remained on the face about five times as long as the emo-form. From the perspective of the receiver it is probable that a

human's capacity to process incoming messages is finite, but what the upper limit is in communication requires further investigation. There is some preliminary evidence suggesting that there is an optimal human transmission rate of information (Klima & Bellugi, 1988; Pellegrino et al., 2011) but these studies only took into consideration lexical information.

Conclusion

We found evidence that the emo-form is consistently used with the sign EKEL 'disgust'. We found that it has scope over the lexical item and that there is a certain degree of idiosyncrasy in exactly how the emo-form is produced although the most common form was mouth opening and tongue protrusion.

In trying to account for the function of the emo-form either phonologically or morphologically, one runs into the problem of apparent redundancy. This is the same problem one has in accounting for mouthings. Phonologically they seem redundant because the manual component of signs is usually distinct enough not to require additional features, and morphologically emo-forms and mouthings do not add new semantic content to the sign, they seem to only repeat the semantic content of the manual component. Following the Zipfian notion of least effort, we propose that this redundancy is only apparent. The use of emo-forms and mouthings must be of benefit to the receiver of the message, or else the sender would not make the extra effort to use additional articulators. This hypothesis can be tested in future psycholinguistic studies.

Given the shared properties between emo-forms, mouthings, enacting actions, facial adverbials, and empty actions, namely that they have scope usually over single lexical items and they have mixed phonological/morphological profiles, we regard them as belonging to one class of phenomena that vary in their origin and their location on a phonological-morphological continuum. We propose that this class be regarded as an additional layer of communication that functions like a parallel lexicon to the manual component in DGS. The relationship between this layer and manual lexical items is analogous in some ways to the relationship between gesture and words, or intonation and words.

We have shown that in typical face-to-face communication at least four different information type layers are stacked; lexical items, intonation, gesture, emotion/intention, and that also within a layer, units can be stacked. One of the future research questions that follows from this analysis is; what is the upper limit to the amount of information that can be stacked by humans during communication?

4. General Discussion

In the above studies I have attempted to establish that facial movements can be used as phonological elements. I interpret the finding of a pseudo-homoviseme effect on a lexical decision task as evidence that visemes can be used as part of the phonological representations deaf individuals have of a spoken language. I interpret the findings on the temporal scope and distribution of disgust expressions on DISGUST signs as evidence that facial expressions are part of the phonological representations of signs. In my review article I addressed the issue of how to interpret the similarities and differences between facial movement types, suggesting that the differences are best seen as variations on three dimensions – semantic, compositional and iconic. In this section I will further address the issue of the similarities and differences between facial movements by comparing my view of the data with that of other researchers. The discussion is structured around the following questions that recur in the literature; (1) how many functions do facial movements have? (2) Does each different function entail independent cognitive systems? (3) What constitutes an independent cognitive system?

4.1 How many functions do facial movements have?

Of interest are the facial movements that have a signaling property, or what I call semiotic facial movements. This excludes facial tics and non-communicative instrumental movements such as chewing. I will start by enumerating the facial movements involved in signed languages as these are clearly made for the purpose of conveying meaning. Based on the literature the following linguistic functions of facial movements are attested: phonological (Elliott et al., 2012; Elliott & Jacobs, submitted; Woll, 2001), morphological (Crasborn et al., 2008), syntactic (Neidle et al., 2000; Wilbur & Patschke, 1999), prosodic (Nespor & Sandler, 1999) and gestural (Sandler, 2009). This categorization is by no means uncontroversial. Particularly there is debate surrounding whether specific movements such as brow raise are prosodic units or syntactic elements (cf. Dachkovsky & Sandler, 2009; R. B. Wilbur & Patschke, 1999) and whether mouthings are phonological elements (Boyes Braem & Sutton-Spence, 2001). Nevertheless, the broader functional category of 'linguistic movements' does seem to be well established.

The next functional category that seems to be generally well established, but also similarly rife with its own internal controversies is the emotion related facial movement. Ekman (2004) defines emotional facial expressions as involuntary facial actions that provide information about internal states to others. They are universal, some are present in other species, and they are a sign that an emotion is occurring. They were selected for in evolution because of their role in social communication. Ekman proposes that at least six universal facial expressions of emotion (happiness, sadness, anger, disgust, fear, surprise) can be identified. There is a family of facial expressions for each basic emotion including variations in intensity. However, given the lack of consensus on what emotions are and what facial expressions have to do with them (Ekman, 2004; Fridlund, 1997; Wierzbicka, 1999) I will refer to them as emotion related facial expressions rather than emotional expressions. The reason that I focus on Ekman's theory of emotion related facial expressions is that it is his theory that is most often referred to in the linguistic literature when making comparisons between linguistic facial movements and

others (e.g. Anderson & Reilly, 1997; de Vos et al., 2009; McIntire & Reilly, 1988; Reilly, 2005), and therefore will facilitate the discussion.

Finally, there are facial movements that are semiotic, but that do not fall neatly into the linguistic or emotion categories as described above, these are often termed communicative facial expressions. These include amongst others the sub-categories of emblems and referential expressions (Eibl-Eibesfeldt, 1975; Ekman, 1979). A common example of an emblem is the negating headshake. Emblems can repeat a word (as in 'headshake' co-occurring with the word 'no') add a separate comment on the words spoken, replace a word within speech, or stand alone. Referential expressions are facial actions used to depict an emotion not currently felt by the person depicting it.

This tripartite distinction of semiotic facial movement functions may be useful for quickly communicating what types of facial movements a researcher is interested in, but it seems to me that as yet too little is known about the similarities and differences between semiotic facial movement types to claim that this categorization corresponds to three independent underlying cognitive systems. I assert this for two reasons: firstly as I already stated above, within the fields of emotion research and linguistics there is no consensus on the fundamental nature of specific expressions. As the scientific definitions of 'emotion', 'communication' and 'language' are still being forged, the type of facial movements attributed to each category remains unstable. Secondly the types of facial expressions subsumed under the communicative category are under-researched. This category seems to include movements that fit into McNeill's (1992) definition of co-speech gestures, while others seem to be similar to the prosodic facial movements of signers (Krahmer & Swerts, 2009). Given that it is now much more broadly accepted that co-speech gestures are a part of language (Kelly et al., 2010) much of the facial movements that where once in the 'communicative' category can be subsumed by the 'linguistic' category.

4.2 Does each different function entail independent cognitive systems?

Contrary to my view however, Reilly and her colleagues (Anderson & Reilly, 1997; McIntire & Reilly, 1988; Reilly, 2005; Reilly & Bellugi, 1996; Reilly et al., 1990a; Reilly et al., 1990b; Reilly et al., 1992) have been making the argument for independent cognitive systems mediating linguistic, affective and communicative uses of facial movements. They are the only group, to the best of my knowledge, to study the acquisition of facial movements by deaf individuals. However I find that their independent systems argument has two very severe limitations; they are inconsistent regarding the distinction they make between communication and affect and they remain very vague regarding what an independent system is.

In Anderson and Reilly, (1997) the cited authors make a distinction between linguistic and communicative functions. They develop an argument based on the use of negation headshake in spoken language, and negation headshake as used in signed languages. They draw the conclusion that: "[there is] strong evidence that the **systems for communication and language** are differentially mediated" (p. 411) [emphasis mine]. However in a later paper Reilly (2005) combines affective and communicative functions:

> "To return to the original questions, the data suggest that the relations among **affect, communication, and language** change with development. Initially, these appear to all be served by one broad-based symbolic communicative system. Then, with the onset of syntax, sometime near the child's second birthday, there is a shift such that the developing linguistic system no longer has free access to the **communicative/affective** behaviors, even when they are semantically and formally pertinent, as with negation. These behavioral changes imply a bifurcation such that the **systems for language and affect** are differentially mediated" (p. 287) [emphasis mine].

Her concluding claim in this quote is now for separate affect and language systems, rather than for separate communication and language systems. These two claims are very different since despite the controversies regarding the nature of emotion, there is high agreement that affect is part of a system dedicated to allowing an animal to respond to the environment as well as motivating an animal to act in the environment (Izard, 2010). In other words there is enough independent evidence for the existence of a system that we label 'affect' and that it exists in animals other than humans, which in turn is evidence that language is not a necessary or sufficient condition for affect, indicating they are to some extent independent systems.

The above inconsistency is not just an artifact of quote mining. Throughout Reilly's 2005 paper, summarizing 15 years of her own and her colleagues work on the acquisition of linguistic facial movements, she nowhere makes a principled distinction between affect and communication and often uses one term or the other or both separated by a slash:

> "(1) What are the developmental relations between **affect, communication, and language**? Can the infant use her **affective/communicative** prowess to bootstrap herself into the linguistic system?" (pp. 267-268) [emphasis mine].

I now turn to the evidence that Anderson and Reilly, (1997) claim strongly supports the hypothesis that communication and language are differentially mediated. Anderson & Reilly (1997) provide data that the acquisition of linguistic facial actions is not a smooth linear process of increasing adult like usage. In the acquisition of emotion words for example, the child displays a 'U' shaped curve as regards accuracy; they start by producing the correct form HAPPY+smile, they then enter a phase of inaccurate production where HAPPY occurs without the appropriate facial action, but eventually they again produce the correct HAPPY+smile form. For the acquisition of negation and other morphological facial actions, signing children first use the negating headshake alone, then the manual negation sign is used but without a headshake, and finally the manual and facial negation components are correctly produced together. They state that this contrasts with the acquisition pattern for other facial action types such as emotional expressions or the negating headshake when used by non-signers. These types of facial actions seem to linearly increase in amount and complexity as the child matures. They conclude that these differences in acquisition are strong evidence that language and communication are two distinct systems.

I argue that the acquisition data is not strong evidence that language and communication are two distinct systems for the following reasons: In an analogous debate regarding the

acquisition of English regular verbs (e.g. walk – walked) and irregular verbs (e.g. sing – sang) it was observed that children showed different patterns of acquisition, particularly that they showed a U-shaped learning curve for the irregular forms. It was proposed that a dual mechanism was involved in the acquisition of the two types of verbs (Pinker & Ullman, 2002). However it was demonstrated that a single system model could account for the acquisition of both types of verbs (McClelland & Patterson, 2002). Furthermore U- shaped learning curves appear in other domains than language and there exist at least four different theories regarding their origin (Rogers, Rakison, & McClelland, 2004). Therefore the presence of a U-shaped learning curve does not necessarily indicate the activity of a syntax module and so one cannot at present rule out the possibility that there is a single system that mediates communicative and linguistic acts despite differences in aquisitional patterns.

The other facet of Anderson and Reilly's (1997) argument relates to the nature of communicative facial movements. They state that unlike linguistic facial movements, communicative facial movements do not appear to be governed by specific rules (p. 415). This appearance may have more to do with the relative lack of research on communicative facial movements that I already mentioned above, than the actual presence of a random behavior. For example, even though co-speech gestures are not as predictable as words, McNeill (1992) clearly showed that there are regularities in their production and that they have a non-redundant communicative function. Since many communicative facial movements seem to be like co-speech gestures, they might show the same regularities, such as synchronization with the peak syllable of a clause.

4.3 What constitutes an independent cognitive system?

The question of whether the different kinds of semiotic facial movements observed are mediated by more than one system, and whether the systems are independent or not would benefit from greater explicitness on part of those claiming that they are. For example all types of facial movement at the end must include a step in which the facial muscles receive an impulse to move. A specific question that would be informative regarding independence of systems would be; is there feedback from production into the system (linguistic or other) that originated the impulse? Does the feedback also 'leek' into the systems that did not motivate that particular facial movement? If feedback leeks into all systems that can activate the facial muscles, then a strong version of independent systems, one in which language, affect, and communication are completely autonomous of each other, is not warranted. There does in fact seem to be some evidence that facial muscle movements feed back into systems that did not motivate them: Niedenthal et al., (2009) found that moving the facial muscles for a non-communicative instrumental purpose such as holding a pencil in one's mouth affects judgments on the emotional content of words.

Before making claims about how many systems are required to account for the facial movement behaviors a closer look at the differences and similarities is required. At present the following is known about the differences; the onsets and offsets of linguistic facial expressions are aligned to the onsets and offsets of the manual component of signs and they have scope over specific linguistic constituents. In contrast emotion related facial expressions and communicative facial expressions do not appear to be tightly synchronized to words

(Baker-Shenk, 1983; Veinberg & Wilbur, 1990; Ronnie B. Wilbur, 2009). It has also been claimed that linguistic facial expressions differ from emotion related facial expressions in the facial muscles they recruit (Herrmann & Steinbach, 2011) however, I am not aware of empirical evidence supporting this. For even Ekman and colleagues (Ekman et al., 2002a, p. 173) who are amongst the leading proponents of the theory that some facial expressions correspond uniquely to discrete emotions, state that there is no complete evidence for exactly which action units (facial muscle movements) correspond to which emotion. The second difference lies in order of acquisition. Emotion related facial expressions appear within the first few months of human life (Izard et al., 1995), followed by communicative facial movements at about one year, and shortly after by linguistic ones at one and a half years of age (Anderson & Reilly, 1997). A third difference lies in their semantics. Wierzbicka (1999) argues that emotion related facial expressions always mean what they mean in the first person present tense orientation i.e.: raised brows means '**I** want to know more **now**'. The data on communicative and linguistic functions of brow raise suggests that they lack the first person present tense orientation and what remains is the core of 'want to know more' or some similar formulation such as 'more information is coming' (Dachkovsky & Sandler, 2009). This process of a semiotic unit losing some of its meaning as it takes on other functions is attested in linguistics and referred to as semantic bleaching (Traugott, 1988).

5. Limitations and Outlook

Given that there are only three studies, to the best of my knowledge, that directly compare the differences in form between linguistic and other facial movements and that the result is that linguistic facial expressions are more strictly timed to words, there is clearly much more that can and should be done. I suggest that the durations of various expression types be measured, that frequencies of expression types be measured, and the frequencies with which they co-occur with other elements such as hand movements or words also be measured. Furthermore cluster analyses on the facial muscles recruited for emotion related expressions and others can be carried out to substantiate the claim that different muscles are recruited for the different types of facial expressions. Comparisons on these variables can then be carried out between adult and child facial movements, hearing and deaf people's facial movements, and across cultures.

In my own work I have only started to collect such data and that which was presented in this dissertation only stems from elicited signing. My next step will be to evaluate the occurrence, timing and frequency of various facial movement types from the free speech sections of my corpus, as well as to compare hearing and deaf facial expressions. Another limitation as regards my more specific claim that facial movements can be used as phonological elements is that the evidence I provide comes from production of sign and perception of written German. In future work I would also gather evidence from perception of signed language to establish whether mouthings and other lexically timed facial movements facilitate responses to perceived signed material. Alongside the continued gathering of data, a development of the models for signed language production (p. 8 above) and the more general model of communication layers (p. 64 above) is also required especially to facilitate the generation of hypotheses for confirmatory studies, as opposed to the largely exploratory ones suggested above.

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Appendix 1. Materials for Study (1)

A. Stimulus Material

Stimulus	Count	Frequency (Low = 1, High = 2)	Category (Pseudohomoviseme = 1 Spelling Control = 2 Word Filler = 3)
lod	1	1	1
wase	2	1	1
leie	3	1	1
tib	4	1	1
roo	5	1	1
rosd	6	1	1
trok	7	1	1
kruk	8	1	1
ais	9	1	1
lit	10	1	1
eit	11	1	1
ahl	12	1	1
wud	13	1	1
wee	14	1	1
feh	15	1	1
apt	16	1	1
jot	17	1	1
lop	18	1	1
hei	19	1	1
gihr	20	1	1
ekke	21	1	1
pfat	22	1	1
kleh	23	1	1
zwisd	24	1	1
nihte	25	1	1
bihne	26	1	1
eckse	27	1	1
draat	28	1	1
zwerk	29	1	1
sirub	30	1	1
grais	31	1	1
pfant	32	1	1
wenus	33	1	1
elent	34	1	1
pfaal	35	1	1
lut	36	1	2
vose	37	1	2
naie	38	1	2
tif	39	1	2
rol	40	1	2
rosk	41	1	2

trof	42	1	2
krut	43	1	2
ois	44	1	2
lin	45	1	2
eip	46	1	2
arl	47	1	2
wuk	48	1	2
wef	49	1	2
feu	50	1	2
aft	51	1	2
jol	52	1	2
lof	53	1	2
wai	54	1	2
girr	55	1	2
efke	56	1	2
pfak	57	1	2
klet	58	1	2
zwisp	59	1	2
nilte	60	1	2
biane	61	1	2
echre	62	1	2
dralt	63	1	2
zwirg	64	1	2
sirul	65	1	2
gruis	66	1	2
pfank	67	1	2
vetus	68	1	2
erend	69	1	2
pfarl	70	1	2
foll	71	2	1
zait	72	2	1
jaar	73	2	1
grunt	74	2	1
baide	75	2	1
gaist	76	2	1
krais	77	2	1
pahr	78	2	1
unt	79	2	1
bihr	80	2	1
liet	81	2	1
naa	82	2	1
oor	83	2	1
ord	84	2	1
amd	85	2	1
mid	86	2	1
zihl	87	2	1
lufd	88	2	1
want	89	2	1
balt	90	2	1

spihl	91	2	1
krafd	92	2	1
hilve	93	2	1
zeuk	94	2	1
fluk	95	2	1
parg	96	2	1
damid	97	2	1
wesde	98	2	1
staal	99	2	1
zwekk	100	2	1
klain	101	2	1
fater	102	2	1
prais	103	2	1
fogel	104	2	1
lenge	105	2	1
vorl	106	2	2
zeif	107	2	2
jahl	108	2	2
grind	109	2	2
befde	110	2	2
gelst	111	2	2
krels	112	2	2
plar	113	2	2
ind	114	2	2
birr	115	2	2
liem	116	2	2
naf	117	2	2
orr	118	2	2
orl	119	2	2
amk	120	2	2
mil	121	2	2
zirl	122	2	2
lufp	123	2	2
wanf	124	2	2
balf	125	2	2
spirl	126	2	2
krafl	127	2	2
hilge	128	2	2
zeul	129	2	2
flum	130	2	2
parp	131	2	2
damil	132	2	2
wesge	133	2	2
staul	134	2	2
zwelk	135	2	2
kleun	136	2	2
viter	137	2	2
prels	138	2	2
sogel	139	2	2

linge	140	2	2
affe	141	1	3
ahm	142	1	3
alm	143	1	3
ampel	144	1	3
ara	145	1	3
aue	146	1	3
baron	147	1	3
beet	148	1	3
belag	149	1	3
boee	150	1	3
boje	151	1	3
brei	152	1	3
dampf	153	1	3
des	154	1	3
dia	155	1	3
dreck	156	1	3
duft	157	1	3
duo	158	1	3
dur	159	1	3
ebbe	160	1	3
ego	161	1	3
eile	162	1	3
eule	163	1	3
falke	164	1	3
fang	165	1	3
farm	166	1	3
fete	167	1	3
filz	168	1	3
fluch	169	1	3
gau	170	1	3
gebet	171	1	3
geier	172	1	3
gel	173	1	3
hab	174	1	3
hain	175	1	3
hanf	176	1	3
hast	177	1	3
hecht	178	1	3
hefe	179	1	3
helm	180	1	3
henne	181	1	3
heu	182	1	3
hexe	183	1	3
huf	184	1	3
imker	185	1	3
jacke	186	1	3
jak	187	1	3
jux	188	1	3

kalk	189	1	3
kamm	190	1	3
kanu	191	1	3
kater	192	1	3
kehle	193	1	3
keim	194	1	3
kerze	195	1	3
klo	196	1	3
kobra	197	1	3
komet	198	1	3
korn	199	1	3
kult	200	1	3
labor	201	1	3
lachs	202	1	3
laken	203	1	3
lamm	204	1	3
latte	205	1	3
lau	206	1	3
laus	207	1	3
lee	208	1	3
lug	209	1	3
lunge	210	1	3
aha	211	2	3
all	212	2	3
alp	213	2	3
alte	214	2	3
april	215	2	3
atem	216	2	3
auf	217	2	3
auge	218	2	3
auto	219	2	3
bank	220	2	3
bau	221	2	3
bauch	222	2	3
berg	223	2	3
bett	224	2	3
bis	225	2	3
blume	226	2	3
blut	227	2	3
boot	228	2	3
dabei	229	2	3
dach	230	2	3
dauer	231	2	3
davon	232	2	3
ding	233	2	3
dom	234	2	3
druck	235	2	3
ehre	236	2	3
ein	237	2	3

ende	238	2	3
engel	239	2	3
enkel	240	2	3
esel	241	2	3
faust	242	2	3
feld	243	2	3
fels	244	2	3
figur	245	2	3
fisch	246	2	3
flut	247	2	3
folge	248	2	3
form	249	2	3
frist	250	2	3
funk	251	2	3
gar	252	2	3
gas	253	2	3
glanz	254	2	3
grube	255	2	3
halle	256	2	3
hand	257	2	3
haut	258	2	3
her	259	2	3
hin	260	2	3
hof	261	2	3
ich	262	2	3
ihr	263	2	3
junge	264	2	3
kader	265	2	3
karte	266	2	3
kern	267	2	3
kino	268	2	3
klage	269	2	3
knie	270	2	3
kopf	271	2	3
kranz	272	2	3
lage	273	2	3
last	274	2	3
leben	275	2	3
leser	276	2	3
licht	277	2	3
loch	278	2	3
lok	279	2	3
mal	280	2	3

B. Control non-words in visemic notation

pseudohomoviseme	control non-word	Viseme control non-word	Exists in Corpus
raich	reuch	[-OI-]	0
mei	fai	[FAI]	0
zaal	zehl	[TE-L]	0
foll	vorl	[FO-L]	0
zait	zeif	[TAIF]	0
jaar	jahl	[IA-L]	0
gelt	neld	[TELT]	0
tail	teul	[TOIL]	0
grunt	grind	[--ITT]	0
baide	befde	[PEF][TE]	0
gaist	gelst	[-ELTT]	0
krais	krels	[--ELT]	0
lod	lut	[LUT]	0
pahr	plar	[PLA-]	0
wase	vose	[FO][TE]	0
leie	naie	[TAI][E]	0
bro	tro	[T-O]	0
unt	ind	[ITT]	0
sits	sitf	[TITF]	0
bihr	birr	[PI--]	0
fesd	fesk	[FET-]	0
golt	golm	[-OLP]	0
lant	lank	[LAT-]	0
kint	kink	[-IT-]	0
liet	liem	[LIEP]	0
hant	hank	[-AT-]	0
faart	farrt	[FA--T]	0
kunsd	kunsk	[-UTT-]	0
pfunt	pfung	[PFU-]	0
buk	bun	[PUT]	0
asd	asg	[AT-]	0
osd	osk	[OT-]	0
axd	axg	[A-T-]	0
tib	tif	[TIF]	0
roo	rol	[-OL]	0
ark	arl	[A-L]	0
rosd	rosk	[-OT-]	0
trok	trof	[T-OF]	0
kruk	krut	[--UT]	0

kalp	kalf	[-ALF]	0
magt	magf	[PA-F]	0
ofd	ofk	[OF-]	0
nih	nis	[TIT]	0
naa	naf	[TAF]	0
oor	orr	[O--]	0
uur	urr	[U--]	0
ord	orl	[O-L]	0
amd	amk	[AP-]	0
mid	mil	[PIL]	0
resd	resg	[-ET-]	0
zihl	zirl	[TI-L]	0
bilt	bilp	[PILP]	0
bant	banf	[PATF]	0
gasd	gasp	[-ATP]	0
lufd	lufp	[LUFP]	0
want	wanf	[FATF]	0
balt	balf	[PALF]	0
hunt	hunk	[-UT--]	0
spihl	spirl	[SPI-L]	0
krafd	krafl	[--AFL]	0
hilve	hilge	[-IL][-E]	0
pungt	punft	[PUNFT]	0
ais	ois	[OIT]	0
lit	lin	[LIT]	0
eit	eip	[AIP]	0
ahl	arl	[A-L]	0
wud	wuk	[FU-]	0
wee	wef	[FEF]	0
feh	feu	[FOI]	0
apt	aft	[AFT]	0
jot	jol	[IOL]	0
lop	lof	[LOF]	0
hei	wai	[FAI]	0
gihr	girr	[-I--]	0
zeuk	zeul	[TOIL]	0
fluk	flum	[FLUP]	0
ekke	efke	[EF-E]	0
neit	neim	[TAIP]	0
pfat	pfak	[PFA-]	0
kleh	klet	[-LET]	0
parg	parp	[PA-P]	0
sant	sanf	[TATF]	0

foier	fauer	[FAU][--]	0
monad	monal	[MOT][AL]	0
abent	arend	[A-][ETT]	0
damid	damil	[TAP][IL]	0
jetst	jetit	[IET][IT]	0
pabst	panst	[PATTT]	0
forsd	forsg	[FO-T-]	0
dochd	dochg	[TO--]	0
zwisd	zwisp	[TFITP]	0
stuul	stull	[STUL]	0
wesde	wesge	[FET][-E]	0
nihte	nilte	[TIL][TE]	0
mihte	milte	[PIL][TE]	0
bihne	biane	[PIA][TE]	0
klots	klotf	[-LOTF]	0
wesbe	wesle	[FET][LE]	0
larfe	larte	[LA-][TE]	0
staal	staul	[STA][UL]	0
eckse	echre	[E-][-E]	0
zwekk	zwelk	[TFEL-]	0
stain	steun	[STOIT]	0
klain	kleun	[-LOIT]	0
fater	viter	[FIT][E-]	0
stard	starm	[STA-P]	0
prais	prels	[P-ELT]	0
artzt	arnzt	[A-TTT]	0
dursd	dursg	[TU-T-]	0
sichd	sichk	[TI--]	0
wahge	warge	[FA-][--]	0
draat	dralt	[T-ALT]	0
bezuk	bezul	[PET][UL]	0
zwerk	zwirg	[TFI--]	0
sirub	sirul	[TI][-UL]	0
grais	gruis	[--UIT]	0
pfant	pfank	[PFAT-]	0
wenus	vetus	[FET][UT]	0
fogel	sogel	[TO][-EL]	0
elent	erend	[E-][ETT]	0
pfaal	pfarl	[PFA-L]	0
lenge	linge	[LI-][-]	0

C. Questionnaire

Guten Tag,

mein Name ist Eeva Elliott von der Freien Universität Berlin. Ich arbeite an einer vom Max Planck Institut (MPI) für Bildungsforschung unterstützten Studie, für die ich untersuche, wie Gehörlose Deutsch lesen. Mein Ziel ist es zu verstehen, wie einzelne Wörter von Gehörlosen gelesen werden. Ich suche daher nach geeigneten Teilnehmern für ein Experiment, bei dem am Computer Wörter und Nicht-Wörter durch Drücken einer entsprechenden Taste eingeteilt werden sollen. Außerdem soll ein kurzer Fragebogen ausgefüllt werden. Das Experiment dauert etwa 1-2 Stunden. Für die Teilnahme wird eine Aufwandsentschädigung von 20 Euro gezahlt. Persönliche Angaben werden selbstverständlich vertraulich behandelt und es werden keine Namen in den Forschungsberichten genannt.

Vielen Dank für Ihre Bereitschaft, mir bei meiner Forschung zu helfen.

Eeva

hava@zedat.fu-berlin.de

Datum: _____

1. Persönliche Angaben:

[*Ich werde in keiner Form persönliche Angaben aus diesem Formular an Außenstehende weitergeben. Dies gilt sowohl für offizielle als auch inoffizielle Zusammenhänge, und sowohl für mündliche als auch schriftliche und elektronische Form.*]

Name:	Geburtstag:	Geschlecht: M___ W___	Dominante Hand: Rechts ___ Links ___

2. Hörfähigkeiten:

Gehörlos: __   Schwerhörig: __
Grad des Hörverlustes (audiometrische Grenzwerte):   (41 to 70 dB HL): _____   (71 to 90 dB HL): _____   (mehr als 91 dB HL):_____
Benutzen Sie ein Hörgerät?   Ja: ____   Nein:____

3. Sprachen:

Sprechen Sie DGS?   Ja: ___Nein: ___   Von Welchem Alter: ____
Sprechen Ihre Eltern DGS?   Mutter: ___   Vater: ___
Haben Sie gehörlose Eltern?   Mutter: ___   Vater: ___

Sprechen Sie andere Sprachen?

    1.   Deutsch: ___   In welchem Alter?___

    2.   Andere: _____ In welchem Alter?___

Was ist Ihre Muttersprache?: _____

In welchem Alter hatten Sie zum ersten Mal Kontakt mit DGS

(bitte ankreuzen)?

1 2 3 4 5 6 7 8 9 10 Jahr/e

- Älter als 10 Jahre? In welchem Alter?___

Wo hatten Sie zum ersten Mal Kontakt mit DGS?

(Mehrfachnennungen möglich)

    3.   Mit den Eltern _____ In welchem Alter?___

    4.   In der Schule _____ In welchem Alter?___

    5.   Sonstige: _____ In welchem Alter?___

Mit wem sprechen sie DGS/Deutsch/eine andere Sprache:

(Mehrfachnennungen möglich)

	DGS	**Deutsch**	**Andere:_____**
Familie			
Freunde			
In der Schule			
Bei der Arbeit			
Andere			

Wie gut können Sie Deutsch?

	Sprechen	Schreiben	Lesen
Sehr Gut			
Gut			
Befriedigend			
Kaum			

4. **Ausbildung**

Schule	Unterrichtssprache
Kindergarten Ja:___ Nein:___	Mündlicher Unterricht? Ja___ Nein___ Unterricht in Gebärdensprache? Ja ___ Nein ___ Lautsprachbegleitende Gebärden? Ja___ Nein___
Grundschule Ja:___ Nein:___	Mündlicher Unterricht? Ja___ Nein___ Unterricht in Gebärdensprache? Ja ___ Nein ___ Lautsprachbegleitende Gebärden? Ja___ Nein___
Sekundarschule Ja:___ Nein:___	Mündlicher Unterricht? Ja___ Nein___ Unterricht in Gebärdensprache? Ja ___ Nein ___ Lautsprachbegleitende Gebärden? Ja___ Nein___
Hochschulausbildung Ja:___ Nein:___	Mündlicher Unterricht? Ja___ Nein___ Unterricht in Gebärdensprache? Ja ___ Nein ___ Lautsprachbegleitende Gebärden? Ja___ Nein___
Berufliche Ausbildung Ja:___ Nein:___	Mündlicher Unterricht? Ja___ Nein___ Unterricht in Gebärdensprache? Ja ___ Nein ___ Lautsprachbegleitende Gebärden? Ja___ Nein___
Andere Ausbildung? Welche?:	

5. **Lesen**

In welchem Alter hat Ihr Leseunterricht begonnen?: ____

In Ihren Freizeit lesen Sie:

gar nicht = 1

weniger als 1 Stunde im Monat = 2

zwischen 1-5 Stunden im Monat = 3

zwischen 5-10 Stunden im Monat = 4

mehr als 10 Stunden im Monat =5

- Bücher: 1 2 3 4 5

- Zeitung: 1 2 3 4 5

- Internet: 1 2 3 4 5

6. **Ihrer Meinung**

Bitte schreiben Sie kurz etwas über Ihre Schulzeit. Wie waren Ihre Lehrer? Konnten die gut DGS? Was würden Sie verändern?

_____
_____
_____
_____
_____
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_____
_____
_____
_____
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_____
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_____
_____

D.   Spelling Test Items

	20 Items for spelling test
1	Zustimmung
2	Ausbeute
3	Frühstück
4	schnurren
5	Achsel
6	Haken
7	Verordnung
8	Masseur
9	Rücklicht
10	vertrauen
11	verschenken
12	angemessen
13	Kontoauszug
14	schmatzen
15	zuzahlung
16	verbessern
17	ekelig
18	feile
19	Krabbe
20	widerstandsfähig

Appendix 2 Materials for Study (2)

The sentences were derived in the following manner: The words for the six basic emotions of Ekman were used in two types of sentences. The first type was direct speech, e.g.,

    1) I am angry at my boss.

The second sentence type was reported speech, e.g.,

    2) My friend said that she is angry at her boss.

The first list consisted of 24 words for various emotions. These words were chosen on the basis of their overtly emotional semantic content. The second list consisted of 40 words forming 4 groups based on their emotional valence and arousal ratings. These words were adapted from (Hofmann, Kuchinke, Tamm, Vo, & Jacobs, 2009). Valence and arousal ratings for the words were taken from the Berlin Affective Word List (Vo et al., 2009). The range for valence is between -3 (very negative) and +3 (very positive), and the arousal range is from 1 (low arousal) to 5 (high arousal). Word frequency measures were taken from CELEX (Baayen et al., 1995) and are given in occurrences per million. The word groups consisted of ten neutral, ten negative highly arousing words, ten negative low arousing words, and ten positive words. All words had a frequency of greater than or equal to 6,33 occurrences per million.

Variables	High Arousal Negative		Low Arousal Negative		Neutral Words		Positive Words	
	M	SE	M	SE	M	SD	M	SE
Emotional Valence	-1.738	0.162	-1.43	0.896	0.098	0.237	1.685	0.242
Arousal	3.9	0.31	3.27	1.002	3.29	0.424	3.561	0.341
Mean Word Frequency	19.7	9.113	23.33	16.683	22.75	13.679	20.433	7.286

A. Corpus Part 1. Sentences:

1. Ich bin verärgert über meinen Chef.

   I am angry at my boss.

2. Mein Freund hat gesagt, dass er über seinen Chef verärgert ist.

   My friend said, that he is angry at his boss.

3. Ich bin angeekelt von Würmen.

   I am disgusted by worms.

4. Mein Freund hat gesagt dass er angeekelt von Würmen ist.

   My friend said that he is disgusted by worms.

5. Ich habe Angst, vor dem Tod.

   I am afraid of death.

6. Meine Schwester hat gesagt, dass sie Angst vor dem Tod hat.

   My sister said that she is afraid of death.

7. Ich bin glücklich meinen Freund wieder zu sehen.

   I am happy to see my friend again.

8. Meine Mutter hat gesagt, dass sie glücklich ist ihre Freundin wieder zu sehen.

   My mother said that she is happy to see her friend again.

9. Ich bin traurig weil mein Hund gestorben ist.

   I am sad because my dog died.

10. Mein Bruder hat gesagt dass er traurig ist weil sein Hund gestorben ist.

    My brother said that he is said because his dog died.

11. Ich bin überrascht von der Nachricht.

    I am surprised by the news.

12. Meine Schwester hat gesagt dass sie überrascht von der Nachricht ist.

    My sister said that she is surprised by the news.

B. Corpus Part 2. Free Speech

Eliciting Question: Es erscheint für Hörende die können nicht DGS, das DGS mehr emotional als Lautsprache ist. Was denken Sie darüber? Stimmen Sie zu? Warum ja/nein?

Eliciting Question Translation: For hearing non-signers, it often seems that DGS is a more emotional language than spoken languages. What do you think about that? Do you agree? Why/not?

C. Corpus Part 3. Emotion Words Set 1

1) Vergnügung	13) Traurigkeit
2) Ärger	14) Befriedigung
3) Missachtung	15) Scham
4) Zufriedenheit	16) Überraschung
5) Ekel	17) Liebe
6) Peinlichkeit	18) Hass
7) Aufregung	19) Schmerz
8) Furcht (vor etw)	20) Verlangen
9) Schuld	21) Genuss
10) Freude	22) Frust
11) Arroganz	23) Panik
12) Entspannung	24) Abhängigkeit

D. Emotion Words Set 2: German Words with Emotional Valence and Arousal Ratings

10 Neutral Words

WORD	EMO_ MEAN	EMO_ STD	AROUSAL_ MEAN	AROUSAL_ STD	Ftot/1Mio
AKZENT	0	0,66666667	3,21052632	1,13426175	11,3333333
ALKOHOL	-0,1	0,73786479	3,5	0,96609178	12,5
FESTUNG	0,1	0,87559504	3,41176471	0,61834694	13,8333333
JUNGFRAU	0,3	0,48304589	2,29411765	1,04670351	13,6666667
JUSTIZ	0,1	0,87559504	3,33333333	1,02899151	14,6666667
POLIZIST	-0,3	0,8232726	3,58823529	1,00366974	41,6666667
SPRUNG	0,38235294	1,1550864	3,33333333	1,02899151	32,1666667
SZENE	0,25	0,91046547	3,8	0,89442719	41,1666667
TEMPO	0,4	0,94032469	3,52941176	1,00732611	38
BEFUND	-0,15	0,87509398	2,9	1,02083557	8,5
Mean	0,09823529		3,290072239		22,75
Standard Deviation	0,2368056		0,42416482		13,6791384

10 High Arousal Negative Words

WORD	EMO_ MEAN	EMO_ STD	AROUSAL_ MEAN	AROUSAL_ STD	Ftot/1Mio
PISTOLE	-1,5	1,1785113	3,94444444	0,8726041	13,6666667
SCHMERZ	-1,7352941	1,35532225	4,16666667	0,85749293	35,6666667
STURZ	-1,6	0,96609178	3,76190476	0,76842449	26
TRAUER	-2,1	0,96790604	3,64705882	1,16946443	14
TRENNUNG	-1,7	0,9486833	4,29411765	0,77174363	20,3333333
VERBOT	-1,8	0,61558701	3,28571429	0,95618289	30,8333333

WORD		EMO_MEAN	EMO_STD	AROUSAL_MEAN	AROUSAL_STD	Ftot/1Mio
WUNDE		-1,75	0,85069631	3,88235294	0,78121323	17,6666667
ZORN		-1,8	1,31656118	4,11764706	0,92752041	21,8333333
SCHOCK		-1,8	0,63245553	4,26315789	1,14707867	8,33333333
SCHRECK		-1,6	0,6992059	4,16666667	0,70710678	8,66666667
Mean		-1,73852941		3,952973119		19,7
Standard Deviation		0,16292484		0,318228871		9,11341434

10 Low Arousal Negative Words

WORD	EMO_MEAN	EMO_STD	AROUSAL_MEAN	AROUSAL_STD	Ftot/1Mio
ANKLAGE	-1,5	0,97182532	3,85714286	0,65465367	24
IRRTUM	-1,0588235	1,15315579	3,22222222	0,7320845	36,3333333
KLAGE	-1,55	0,68633274	3,47058824	1,06757008	27,8333333
KLINIK	-1	1,1697953	3,3	1,08093527	18,8333333
MANGEL	-1,9	0,56764621	3,0625	0,99791449	56,3333333
SKANDAL	-1,3	1,05934991	3,5	1,24852855	10,3333333
VERZICHT	-1,3	1,05934991	2,94444444	0,93759531	38,6666667
DELIKT	-1,6	0,50262469	3,41176471	1,22774303	6,66666667
DUMMHEIT	-1,9	0,87559504	3	0,93541435	8
SCHROTT	-1,2	0,91893658	3	1,13759292	6,33333333
Mean	-1,43088235		3,276866247		23,3333333
Standard Deviation	0,31611605		0,289736192		16,68314

10 Positive Words

WORD	EMO_ MEAN	EMO_ STD	AROUSAL_ MEAN	AROUSAL_ STD	Ftot/1Mio
AUFSTIEG	1,8	0,42163702	3,29411765	1,04670351	23,6666667
EHRGEIZ	1,5	1,1785113	3,55555556	0,70479219	11,1666667
GEBURT	1,9	0,91190951	4,17647059	0,882843	24,5
GENIE	1,9	0,71818485	3,70588235	0,91955872	11,8333333
HUMOR	2,15	0,74515982	3,8125	0,65510813	12
IMPULS	1	0,66666667	3,63157895	1,30002249	20,8333333
LUST	2,1	0,87559504	3,66666667	1,02899151	30,3333333
REICHTUM	1,5	0,52704628	3,35294118	1,22173936	18,8333333
REKORD	1,3	1,12857619	3,52631579	1,1722922	31,3333333
RUHM	1,7	0,67494856	2,88888889	1,3234931	19,8333333
Mean	1,685		3,561091763		20,4333333
Standard Deviation	0,36213104		0,341023718		7,28655111

Curriculum Vitae

For reasons of data protection,

the curriculum vitae is not published in the electronic version.

Erklärung

Die Studien dieser Dissertationsschrift wurden in marginal modifizierten Versionen in internationalen Fachzeitschriften veröffentlicht oder stehen kurz vor der Einreichung:

Studie 1:

Elliott, E. A., Braun, M., Kuhlmann, M., & Jacobs, A. M. (2012). A Dual-Route Cascaded Model of Reading by Deaf Adults: Evidence for Grapheme to Viseme Conversion. *Journal of Deaf Studies and Deaf Education, 17*(2), 227-243. doi: 10.1093/deafed/enr047

Studie 2:

Elliott, E. A., & Jacobs, A. M. (2013). Facial expressions, emotions, and sign languages. *Frontiers in Psychology*. doi:10.3389/fpsyg.2013.00115

Studie 3:

Elliott, E. A., & Jacobs, A. M. (submitted). Phonological and Morphological Faces: Disgust Signs in German Sign Language. *Sign Language and Linguistics*.

Die angeführten Ko-Autoren können bestätigen, dass ich für das Entstehen dieser Studien hauptverantwortlich war. Hiermit versichere ich, dass ich die vorliegende Arbeit selbständig verfasst habe. Andere als die angegebenen Hilfsmittel habe ich nicht verwendet. Die vorliegende Arbeit war nicht Gegenstand eines anderen Promotionsverfahrens.

Berlin, den 02 Mai 2013

Eeva A. Elliott