**Fachbereich Erziehungswissenschaft und Psychologie**

**der Freien Universität Berlin**

# Elektrophysiologische Korrelate sozialer Exklusion und Inklusion im Cyberball-Paradigma

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# Abstract

The most widely used paradigm to study the effects of social exclusion in an experimentally controlled environment is a virtual ball-tossing game called "Cyberball". According to the need-threat model (Williams, 2007) four fundamental social needs (belonging, self-esteem, meaningful existence, and control) are threatened after social exclusion compared to inclusion. The model states that this reflexive response serves as an early detection system for social exclusion. It proposes that there is a specific neural basis for the perception of social need threat. The aim of the present work was to identify electrophysiological correlates of social inclusion and exclusion in the Cyberball paradigm, and to reveal the underlying mechanisms inducing these effects. In a series of experiments a partial exclusion condition was used to analyze the processing of ball reception under various conditions. The P3 component was the only event-related brain potential which was reliably affected by social exclusion or inclusion. By directly comparing the Cyberball and oddball paradigm it was shown that similar processes are elicited in both tasks. The electrophysiological effects obtained during Cyberball were largely independent from the appraisal of a situation as social or non-social or from a feeling of exclusion. In another experiment the probability of ball reception was separated from the expectancy for ball reception. Evidence was provided that the violation of expectancy for social involvement can explain the effects on the P3 amplitude, and on perceived social exclusion. Therefore it was proposed to include the processing of expectancy violations in the need-threat model for social exclusion to integrate the findings of different fields of psychological research, like social psychology and neuroscience.

# Zusammenfassung

Das Paradigma, das am häufigsten genutzt wird, um die Effekte von sozialem Ausschluss unter experimentellen Bedingungen zu untersuchen, ist ein virtuelles Ballspiel namens „Cyberball“. Verglichen mit einer Einschlusssituation werden durch den Ausschluss vier fundamentale soziale Bedürfnisse (Zugehörigkeit, Selbstwert, Sinn der eigenen Existenz und Kontrolle) bedroht (Williams, 2007). Diese Reaktion wird im Rahmen des Need-Threat-Modells für sozialen Ausschluss als reflexiv beschrieben und soll den Charakter eines Frühwarnsystems haben, das auch neuronal implementiert sein soll. Ziel der Arbeit war es, in einer Reihe von Experimenten die beteiligten Prozesse durch die Erfassung ereigniskorrelierter Hirnpotenziale zu identifizieren, die bei der Verarbeitung von sozialem Ein- und Ausschluss im Cyberball-Paradigma aktiviert werden. Mithilfe eines partiellen Ausschlusses wurde die Verarbeitung des Ballerhalts in verschiedenen Situationen untersucht. Als einzige Komponente, die reliabel auf sozialen Ein- oder Ausschluss reagiert, konnte die P3-Komponente identifiziert werden. Durch einen direkten Vergleich des Cyberball- und Oddball-Paradigmas wurde nachgewiesen, dass in beiden Paradigmen ähnliche Prozesse aktiviert werden und die elektrophysiologischen Effekte unabhängig von der wahrgenommenen Bedürfnisbedrohung auftraten. Auch wurden sie weitestgehend nicht davon beeinflusst, ob eine Situation als sozial wahrgenommen wurde oder nicht. Desweiteren konnte durch eine experimentelle Trennung der Wahrscheinlichkeit des Ballerhalts von der Erwartung auf den Ballerhalt gezeigt werden, dass die Verletzung von Erwartungshaltungen sowohl die Effekte auf der Ebene der P3 als auch das wahrgenommene Ausschlussgefühl im Cyberball-Paradigma erklären kann. Es wird vorgeschlagen, diesen Mechanismus in das Need-Threat-Modell mit aufzunehmen, um die neurowissenschaftlichen und sozialpsychologischen Befunde integrieren zu können.

# 1. Einleitung

Ein Thema, das in den vergangenen Jahren viel Beachtung gefunden hat, ist der soziale Ausschluss, auch als Ostrazismus bezeichnet (z.B. Williams, 2007). Durch tragische Vorkommnisse wie Amokläufe, in denen die Täter oft chronischem Ostrazismus ausgesetzt waren (Leary, Kowalski, Smith & Phillips, 2003), oder die zunehmende gesellschaftliche Relevanz von verwandten Themen wie Mobbing oder Bullying hat sich auch die psychologische Forschung verstärkt mit dem Thema auseinander gesetzt. Hierbei spielen vor allem die langfristigen Effekte von chronischem sozialem Ausschluss eine Rolle, die in Einsamkeit, Hilflosigkeit und Depression münden und auch körperliche Leiden und kognitive Einbußen begünstigen können (Baumeister, Twenge & Nuss, 2002; Hawkley & Cacioppo, 2010; Williams & Zadro, 2001). Was allerdings geschieht davor? Wie wird sozialer Ausschluss verarbeitet, welche sofortigen Konsequenzen können sich ergeben?

Ostrazismus wird als „being ignored or excluded" (Williams, 2007, S.429) definiert, unabhängig davon, ob dieses Verhalten intentional geschieht oder nur von einer Person als ausschließend wahrgenommen wird (Hartgerink, van Beest, Wicherts & Williams, 2015; Williams, 2007). Während demnach zwischen Ostrazismus (*ostracism*) und sozialem Ausschluss (*social exclusion*) nicht klar unterschieden werden kann, so dass diese Begriffe in der vorliegenden Arbeit synonym verwendet werden, sind sie abzugrenzen von sozialer Zurückweisung (*rejection*), die in der Regel einen intentionalen Aspekt mit einschließt.

Von Williams und Kollegen wurde ein Modell entwickelt, das verschiedene Phasen des sozialen Ausschlusses beschreibt, das Need-Threat-Modell (Williams, 2007; Williams & Zadro, 2001; Williams & Zadro, 2005). Es postuliert, dass zunächst in einer reflexiven Phase die negative Stimmung steigt und vier fundamentale soziale Bedürfnisse verletzt werden, und zwar die Bedürfnisse nach Zugehörigkeit, Selbstwert, Sinn der eigenen Existenz und Kontrolle. Diese als schmerzhaft empfundene

Reaktion soll einen „präkognitiven“ Charakter haben und als Frühwarnsystem für sozialen Ausschluss dienen. Sie soll weitestgehend unabhängig von individuellen oder situativen Faktoren auftreten (Buckley, Winkel & Leary, 2004; Gonsalkorale & Williams, 2007; Masten et al., 2009; van Beest & Williams, 2006). Denn evolutionär bedingt ist es für Menschen wichtig, sich der Zugehörigkeit zu einer Gruppe sicher sein zu können, weil es ansonsten zu lebensbedrohlichen Situationen kommen kann (Williams, 2007). Auf die reflexive folgt eine reflektive Phase, in der versucht wird, die Bedürfnisbefriedigung wiederherzustellen. In dieser kann z.B. die Situation neu bewertet oder durch Verhaltensänderungen wieder Anschluss gewonnen werden. Dann spielen auch situative Faktoren wie die Quelle des Ausschlusses, mögliche Gründe und individuelle Faktoren wie Persönlichkeitseigenschaften und eigene Vorerfahrungen eine Rolle (Romero-Canyas, Downey, Berenson, Ayduk & Kang, 2010; Sijtsema, Shoulberg & Murray-Close, 2011; Zadro, Boland & Richardson, 2006). Wenn es nicht gelingt, die Bedürfnisse wiederherzustellen und sozialer Ausschluss langfristig auftritt, kommt es zu einer Phase der Resignation mit den oben geschilderten schwerwiegenden Folgen (Hartgerink et al., 2015).

Um sozialen Ausschluss oder Zurückweisung unter experimentellen Bedingungen untersuchen zu können, können aus ethischen und praktischen Erwägungen heraus nur die kurzfristigen Effekte analysiert werden. Dafür wurden eine Reihe von Paradigmen entwickelt, um Gefühle sozialen Ausschlusses unter mehr oder weniger kontrollierten Bedingungen erzeugen zu können. Als eine indirekte, aber effektive Methode gilt z.B. das Life-Alone-Paradigma, in dem Probanden[1] – vermeintlich aufgrund eines Testergebnisses – mitgeteilt wird, sie würden im Alter alleine ohne Freunde oder Familie leben (z.B. Baumeister et al., 2002; Twenge, Baumeister, Tice &

[1] Zur besseren Lesbarkeit wird in der vorliegenden Arbeit in der Regel die männliche Form benutzt. Sämtliche Pronomen und personenbezogene Bezeichnungen sind geschlechtsneutral zu verstehen.

Stucke, 2001). Es wurden auch Paradigmen entwickelt, in denen Probanden direkt einer Ausschlusssituation ausgesetzt werden, wie durch eine Nicht-Beachtung bei Gesprächen oder virtuell in Chatrunden (Williams et al., 2002; Zadro & Williams, 2006). Ein weiteres Paradigma ist ein Ballspiel („Ball-Tossing-Paradigma“), in dem der Proband nach einer gewissen Zeit nicht mehr angespielt wird (Williams, 1997). Dieses hat den Vorteil, dass eine Versuchsperson nicht explizit zurückgewiesen, sondern ignoriert wird und damit eher der Definition von sozialem Ausschluss oder Ostrazismus folgt.

# 2. Methode und Zielstellung

Das wahrscheinlich am häufigsten eingesetzte Verfahren ist das Cyberball-Paradigma (Williams, Cheung & Choi, 2000; Williams & Jarvis, 2006, siehe Abbildung 1). In Anlehnung an das oben erwähnte Ball-Tossing-Paradigma wird hierbei den Versuchspersonen gesagt, sie würden ein virtuelles Ballspiel spielen, in dem sie mit (in der Regel) zwei Mitspielern über das Internet verbunden sind. Ziel sei es, die visuelle Vorstellungskraft zu messen. Diese Coverstory dient dazu, die Probanden von der eigentlichen Fragestellung abzulenken.

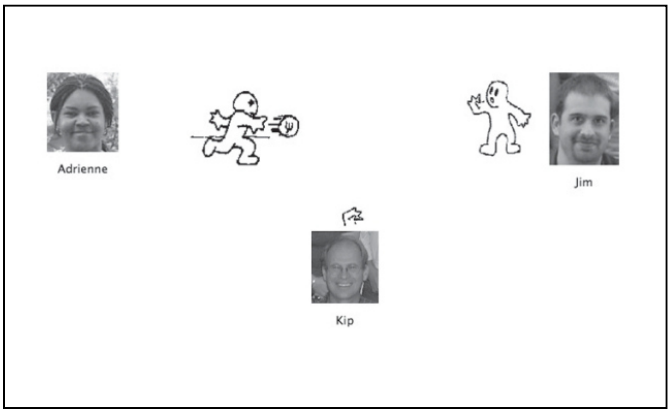


**Abbildung 1:** Bildschirmausschnitt des Cyberball-Paradigmas nach Williams und Kollegen (Quelle: Williams & Jarvis, 2006, S. 176). Die Versuchsperson (hier „Kip“) bekommt den Ball in der Einschlussbedingung zu etwa einem Drittel und in der Ausschlussbedingung nur ein paar Mal zu Beginn des Spiels und dann gar nicht mehr.

Oftmals wird ein Zwischengruppendesign verwendet (Hartgerink et al., 2015), wobei in der einen Gruppe die Probanden fair behandelt werden, also zu etwa einem Drittel den Ball bekommen, und in der anderen Gruppe der Ball nur in den ersten Durchgängen und dann in den restlichen ca. 30 Pässen gar nicht mehr der Versuchsperson zugespielt wird. Die Gedanken und Gefühle während des Spiels werden im Anschluss mittels Selbstbericht erhoben. Dabei wird mithilfe des Need Threat

Questionnaire (NTQ, Williams et al., 2000) unter anderem die Ausprägung der vier grundlegenden Bedürfnisse Zugehörigkeit, Selbstwert, Sinn der eigenen Existenz und Kontrolle erfasst. Die Probanden sollen außerdem einschätzen, wie oft sie den Ball im Spiel bekommen und in welchem Ausmaß sie sich ein- oder ausgeschlossen gefühlt haben.

Das Cyberball-Paradigma hat viele Vorteile und bietet ein großes Potential für Variationsmöglichkeiten. Variablen wie die Ballerhaltenswahrscheinlichkeit, Dauer des Spiels bzw. Anzahl der Ballwürfe, Anzahl oder Identität der Mitspieler können problemlos verändert werden. Es ist leicht durchzuführen und dauert nicht lange (meist unter zehn Minuten), kann aber zuverlässig Ostrazismusgefühle induzieren, wie erst jüngst in einer Metaanalyse von 120 Cyberball-Studien bestätigt wurde (Hartgerink et al., 2015). Aufgrund seines virtuellen und abstrakten Charakters hat es keine nachhaltig negativen Einflüsse auf die Versuchspersonen (Garczynski & Brown, 2014).

In den letzten Jahren wurde das Cyberball-Paradigma nicht nur in reinen Fragebogenstudien, sondern zunehmend auch in bildgebenden und elektrophysiologischen Studien eingesetzt. Das bietet den Vorteil, dass neben dem retrospektiven Selbstbericht auch eine Online-Messung zur Verfügung steht, die die Verarbeitung von sozialem Ein- und Ausschluss während des Spiels erfassen kann. Die meisten Experimente wurden mit funktioneller Magnetresonanztomographie (fMRT) durchgeführt. Als bekanntestes Beispiel sollen hier die Befunde von Eisenberger und Kollegen (z.B. Eisenberger, 2012; Eisenberger, Lieberman & Williams, 2003) genannt werden, die Aktivierungen im dorsalen anterioren cingulären Cortex (dACC) und in der anterioren Insula während des sozialen Ausschlusses gemessen haben, also in Hirnregionen, die auch an der Verarbeitung von physischem Schmerz beteiligt sind (Rainville, Duncan, Price, Carrier & Bushnell, 1997).

Vergleichsweise wenige Studien haben Elektroenzephalographie (EEG) und die Analyse von ereigniskorrelierten Hirnpotenzialen (EKP) benutzt, um sozialen Ausschluss zu untersuchen – in den letzten Jahren hat sich die Befundlage allerdings langsam erhöht. Dabei gibt es einen entscheidenden Vorteil von EEG gegenüber bildgebenden Verfahren wie fMRT, die eine sehr hohe räumliche Auflösung bieten und damit die Quellen der Aktivität gut lokalisieren können, allerdings eine schlechte zeitliche Auflösung besitzen. EEG-Signale können millisekundengenau aufgezeichnet werden, weshalb diese Methode im Besonderen dazu geeignet ist, mögliche Korrelate eines von Williams und Kollegen (z.B. Williams, 2007) postulierten schnell reagierenden, „präkognitiven" Frühwarnsystems zu identifizieren.

Am Fachbereich wurde eine EEG-kompatible Version des Cyberball-Paradigmas entwickelt (Gutz, Küpper, Renneberg & Niedeggen, 2011), die – in modifizierten Versionen – die Grundlage für die Experimente diente, die im Rahmen der vorliegenden Arbeit durchgeführt wurden (siehe Abbildung 2). Vier wichtige Änderungen wurden gegenüber der ursprünglichen Version von Williams und Kollegen (z.B. Williams & Jarvis, 2006) vorgenommen, um den Ansprüchen einer EEG-Ableitung gerecht zu werden: 1) Die Flugbewegung des Balls wurde nicht dargestellt, sondern er sprang von einer Position zur nächsten, um auf Millisekundenebene die relevanten Ereignisse triggern zu können. 2) Um das Ereignis „Ballerhalt der Versuchsperson" (Ereignis *self*) in verschiedenen Kontexten analysieren zu können, wurde ein partieller Ausschluss anstelle eines kompletten Ausschlusses eingesetzt. Gutz et al. (2011) konnten zeigen, dass eine Reduktion des Ballerhalt von 33 auf 17 Prozent bei drei Spielern ausreicht, um die sozialen Bedürfnisse zu bedrohen. 3) In Fragebogenstudien werden etwa 30 Ballwürfe pro Bedingung gespielt, die allerdings aufgrund der Erfordernisse einer EKP-Analyse nicht ausreichen. Damit auch im partiellen Ausschluss genügend Durchgänge des Ereignisses *self* für die Bildung von Averages zur Verfügung standen, wurde das Spiel auf mindestens 200 Ballwürfe pro Bedingung verlängert. 4) Während in vielen reinen Fragebogenstudien ein Zwischengruppendesign verwendet wird, wurde hier ein Messwiederholungsdesign eingesetzt, in dem die Versuchspersonen zwei Spielblöcke durchlaufen, was in neurophysiologischen Experimenten häufig der Fall ist (Hartgerink et al., 2015). Wie in anderen Studien auch wurden die Fragebögen nach dem Spiel ausgegeben. Es wurde eine deutsche Übersetzung des NTQ verwendet (Grzyb, 2005). Um die Coverstory aufrechterhalten zu können, wurden beide Fragebögen – einer pro Block – erst nach dem Spiel ausgegeben (siehe Anhang für eine Auflistung der Items und Skalen). Auch hier konnte bereits gezeigt werden, dass die Versuchspersonen im Nachhinein in der Lage sind, zwischen den beiden Spielblöcken zu unterscheiden (Gutz et al., 2011).

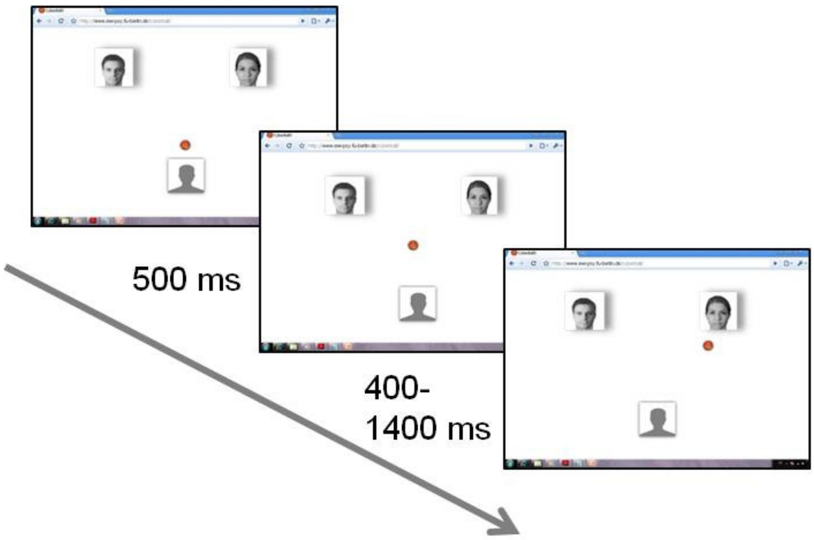


**Abbildung 2:** Modifiziertes Cyberball-Paradigma. Die Position der Versuchsperson (dargestellt durch eine Silhouette) befand sich immer am unteren Rand des Bildschirms. Zwischen den relevanten Ereignissen (*self* und *other*) erschien der Ball für 500 ms in der Mitte des Bildschirms. Die „Reaktionszeit" der virtuellen Mitspieler betrug zwischen 400 und 1400 ms.

Die zentralen Befunde von Gutz et al. (2011), die auch als Ausgangspunkt für die Experimente der Dissertation dienten, waren folgende: Der Ballerhalt der Versuchsperson (Ereignis *self*) löste einen N2-P3-Komplex aus (siehe Abbildung 3). Die N2-Amplitude wurde durch die Wahrscheinlichkeit des Ballerhalts nicht beeinflusst, war aber nach dem Ereignis *self* stärker ausgeprägt als nach dem Ereignis *other* (Ballerhalt eines Mitspielers) und spiegelt damit möglicherweise die Aufgabenrelevanz des Reizes wider. Die P3-Amplitude auf das Ereignis *self* war im Ausschluss größer als im Einschluss.

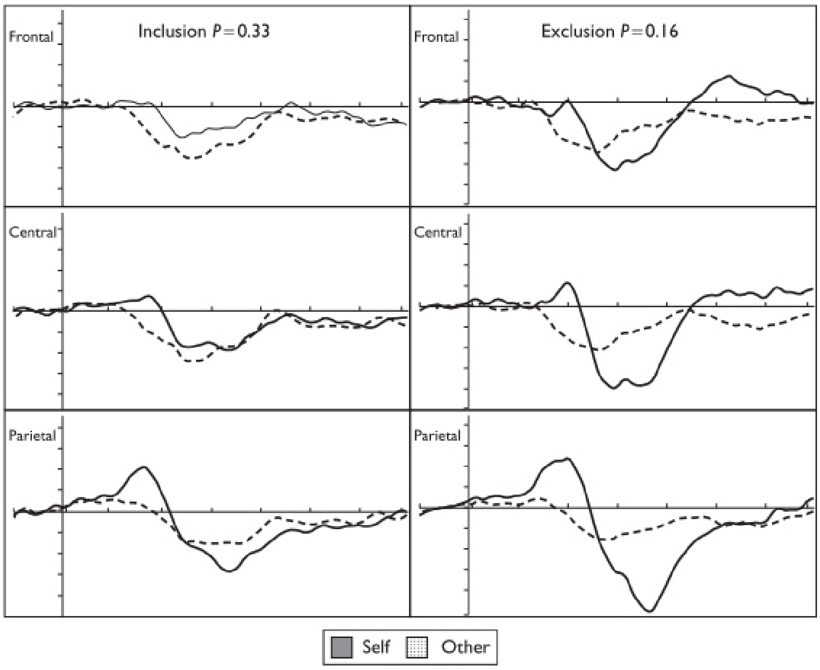


**Abbildung 3:** EKP-Befunde von Gutz et al. (2011, S. 456). Der Ballerhalt der Versuchsperson (Ereignis *self*) löste einen N2-P3-Komplex aus. Die Amplitude der P3-Komponente war während des Ausschlusses (*Exclusion*) verglichen mit dem Einschluss (*Inclusion*) erhöht.

Unter Bezugnahme auf das Oddball-Paradigma wurde die Erhöhung des P3-Komplexes[2], der aus einer zentralen P3a- und einer parietalen P3b-Komponente bestand, mit der Wahrscheinlichkeit des aufgabenrelevanten Reizes (Zielreiz oder Tar-

[2] Die Taxonomie ist nicht immer eindeutig und hat sich historisch gewandelt. In der Regel werden die Bezeichnungen „P300" und „P3b-Komponente" und oft auch „P3" synonym verwendet. Häufig wird jedoch auch „P3" als Überbegriff für die fronto-zentrale P3a und die parietale P3b genutzt.

get im Oddball-Paradigma) in Verbindung gebracht: Es ist bekannt, dass die Amplitude der P3-Komponente von der Wahrscheinlichkeit des Zielreizes oder der Erwartung auf diesen Reiz abhängt (Duncan-Johnson & Donchin, 1977). Dieser in der vorliegenden Arbeit als „P3-Effekt" bezeichnete Befund konnte also auch im Cyberball-Paradigma nachgewiesen werden. In Bezug auf das Ereignis *self* fanden Gutz et al. (2011) Korrelationen zwischen erlebter Ostrazismusintensität und der P3b-Amplitude sowie der negativen Stimmung und der P3a-Amplitude. Es wurde vermutet, entsprechend dem Modell von Williams und Kollegen (z.B. Williams & Zadro, 2005), dass die affektive Verarbeitung, repräsentiert durch die P3a, eher mit dem präkognitiven Warnsystem in Zusammenhang steht und die P3b eine kontrollierte kognitive Verarbeitung widerspiegelt (Gutz et al., 2011).

Auch in anderen EKP-Studien konnte ein Zusammenhang zwischen der P3-Amplitude und dem sozialen Ausschlussempfinden nachgewiesen werden (Crowley, Wu, Molfese & Mayes, 2010; Kawamoto, Nittono & Ura, 2013; Themanson, Khatcherian, Ball & Rosen, 2013), allerdings bleibt der zugrunde liegende Mechanismus weiter offen und es ist unklar, ob diese Komponente Ausdruck eines neuronalen Alarmsystems für sozialen Ausschluss ist, als dessen Korrelat sie teilweise interpretiert wurde. Diese Studien fokussierten sich in der Regel auf die Ereignisse *other*, also auf den Ballerhalt der virtuellen Mitspieler. Es konnte auch eine erhöhte N2-Komponente nach dem Ereignis *other* gefunden werden, unabhängig davon, ob die Gesamtsituation einschließend oder ausschließend war (Themanson et al., 2013). Daher wurde die N2 als Korrelat des Frühwarnsystems interpretiert, das schon bei kleinsten Hinweisen auf sozialen Ausschluss aktiviert wird. Dieses Ergebnis stand im Einklang mit fMRT-Studien, die eine Aktivierung im konfliktverarbeitenden ACC gefunden hatten (z.B. Eisenberger et al., 2003).

Als übergeordnete Fragestellung der Dissertation wurde formuliert, welche elektrophysiologischen Korrelate von sozialem Ein- und Ausschluss im Cyberball-Paradigma identifiziert werden können und welche kognitiven oder emotionalen

Mechanismen für die gefundenen Effekte verantwortlich sind. Da insbesondere auf die Ähnlichkeit zwischen dem Cyberball- und dem Oddball-Paradigma eingegangen werden sollte, die in der Forschung bisher kaum Beachtung gefunden hat, lag der Fokus auf dem Ereignis *self* (Ballerhalt der Versuchsperson). Um allerdings die Ergebnisse mit anderen Arbeitsgruppen vergleichen zu können, wurden die Analysen auf das Ereignis *other* (Ballerhalt der Mitspieler) ausgeweitet. Desweiteren sollten Postulate des Need-Threat-Modells empirisch auf Fragebogen- und elektrophysiologischer Ebene überprüft werden. Die EKP-Befunde sollten dazu dienen, ein mögliches neuronales Alarmsystem für sozialen Ausschluss zu identifizieren.

# 3. Zusammenfassung der Befunde

Im Folgenden werden die Hauptfragestellungen der Dissertation spezifiziert und anhand der durchgeführten Studien beantwortet.

## 3.1 Hat die Glaubwürdigkeit des sozialen Settings einen Einfluss auf das Erleben und die Verarbeitung von sozialem Ausschluss?

**Fragestellung und Methode.** Auch wenn den Versuchspersonen die Information gegeben wird, dass sie beim Cyberball-Spiel mit anderen Mitspielern über das Internet verbunden sind, konnten wir anekdotische Hinweise dafür finden, dass viele diese Coverstory nicht glaubten. In früheren Studien wurde jedoch ein Ausschlussempfinden auch dann zuverlässig induziert, wenn die Probanden wussten, dass sie von programmierten Mitspielern ausgeschlossen wurden (Zadro, Williams & Richardson, 2004). In anderen sozialen Austauschparadigmen hingen die behavioralen und neurophysiologischen Reaktionen allerdings von der (vermeintlichen) Art des Interaktionspartners (Mensch oder Computer) ab (z.B. Rilling, Sanfey, Aronson, Nystrom & Cohen, 2004; van't Wout, Kahn, Sanfey & Aleman, 2006). In vielen Cyberball-Studien wird ein sogenannter „manipulation check“ durchgeführt (Zadro et al., 2004), aber die Glaubwürdigkeit wird in der Regel nicht systematisch variiert oder erfasst (Novembre, Zanon & Silani, 2015).

Es ergaben sich folgende Fragestellungen:

**Führt eine erhöhte Glaubwürdigkeit der Spielsituation zu einem veränderten Erleben des sozialen Ausschlusses? Lässt sich dadurch der P3-Effekt manipulieren?**

In dem Experiment (Manuskript Nr. 1: Weschke & Niedeggen, 2013) wurden 30 Probanden einer von zwei Gruppen zugewiesen: In einer Standardbedingung (Gruppe *Internet*) wurde den Versuchspersonen mitgeteilt, sie würden mit zwei anderen Mitspielern über das Internet verbunden sein, die auf dem Bildschirm durch zwei Fotos dargestellt wurden. In der Experimentalbedingung (Gruppe *Presence*) saßen die Versuchspersonen mit ihren vermeintlichen Mitspielern gemeinsam im Labor (siehe Abbildung 4). Die Spieler wurden durch Buchstaben an den jeweiligen Positionen repräsentiert. Beide Gruppen durchliefen zwei Blöcke des Cyberball-Spiels mit jeweils 200 Durchgängen: Im ersten Block erhielten sie zu 33 und im zweiten Block zu 17 Prozent den Ball.

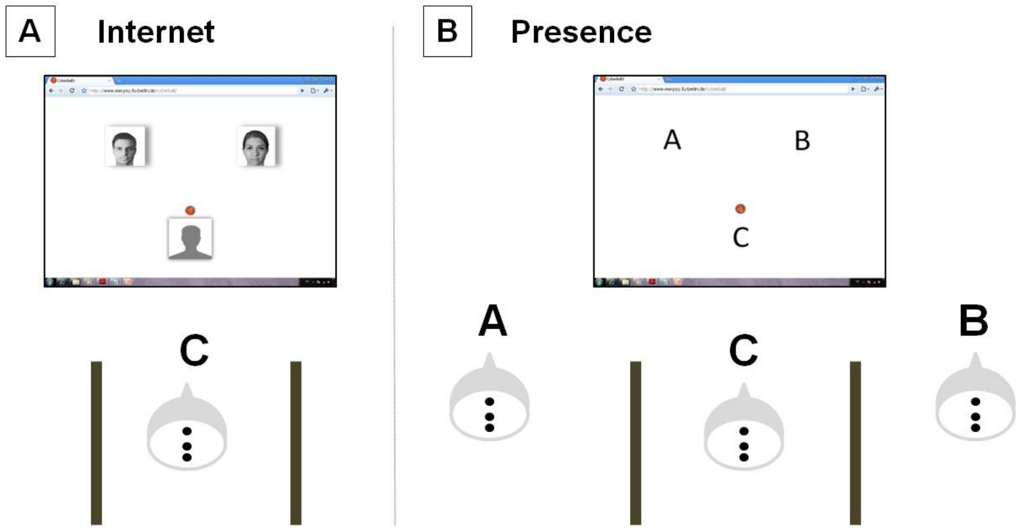


**Abbildung 4:** Darstellung des experimentellen Aufbaus der beiden Gruppen *Internet* (A) und *Presence* (B). Der Versuchsperson wurde die Position „C“ zugewiesen. In der *Presence*-Gruppe waren die vermeintlichen Mitspieler im Labor anwesend, konnten ihre Positionen „A“ und „B“ allerdings nur in den Probedurchgängen steuern.

**Zentrale Ergebnisse.** Durch die experimentelle Manipulation war die Glaubwürdigkeit der sozialen Coverstory in der Gruppe *Internet* verglichen mit der Gruppe *Presence* signifikant reduziert. Die vier fundamentalen sozialen Bedürfnisse hingegen waren in beiden Gruppen gleichermaßen nach dem Ausschluss bedroht und die negative Stimmung erhöht. Die EKPs im Bereich der P3 (hier unterteilt in eine frühere, zentrale P3a und eine spätere, parietale P3b), ausgelöst durch das Ereignis *self*, waren in beiden Gruppen während des Ausschlusses verglichen mit dem Einschluss erhöht (siehe Abbildung 5). Auch hier wurde der Effekt des Ausschlusses nicht durch die Gruppenzugehörigkeit moduliert.

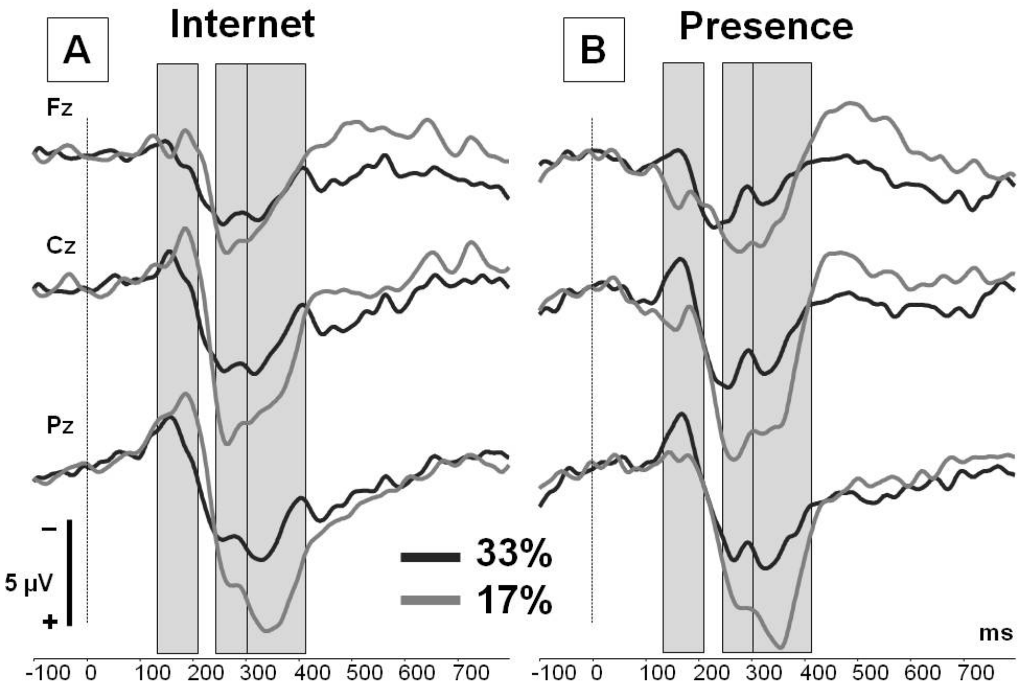


**Abbildung 5:** Grand Averages der experimentellen Gruppen *Internet* (A) und *Presence* (B) in der Inklusionsbedingung (schwarze Linien) und Exklusionsbedingung (graue Linien). Markiert sind die Zeitbereiche der N2 (130-210 ms), P3a (240-300 ms) und P3b (300-410 ms).

**Bedeutung der Befunde.** Die Ergebnisse bestätigen frühere Befunde, in denen nicht nur gezeigt wurde, dass auch vorgegebenes Verhalten der Mitspieler oder computergenerierte Mitspieler den Ausschlusseffekt hervorrufen können (Zadro et al., 2004), sondern auch, dass die Bedrohung von fundamentalen Bedürfnissen unabhängig vom Kommunikationsmedium ist (Williams et al., 2002). Die vorliegende Studie erweitert die Befunde auf partiellen Ausschluss und bestätigt insofern das Need-Threat-Modell, dass situative Faktoren – hier die Glaubwürdigkeit der Coverstory bzw. die physische Anwesenheit der Mitspieler – das Erleben des sozialen Ausschlusses nicht modulieren.

Die elektrophysiologischen Ergebnisse konnten bestätigen, dass die P3-Komponente sensitiv auf Ostrazismus reagiert („P3-Effekt“). Es konnte allerdings kein korrelativer Zusammenhang zwischen den NTQ-Skalen und den P3-Amplituden nachgewiesen werden, so dass eine Bestätigung dafür, dass die P3a ein Korrelat des neuronalen Alarmsystems und die P3b ein Korrelat der wahrgenommenen Ostrazismus-Intensität ist, nicht gefunden werden konnte (vgl. Gutz et al., 2011). Trotz fehlender Korrelationen wurde festgestellt, dass eine (auch subjektiv wahrgenommene) Reduktion des Ballerhalts zu einer Bedrohung von fundamentalen sozialen Bedürfnissen und einer Erhöhung der P3-Amplituden geführt hat – unabhängig von der Erhöhung des Realitätsgrades des sozialen Settings. Es konnte also keine Dissoziation von EKP-Daten (auf der Ebene der P3) und den Fragebogendaten nachgewiesen werden. Allerdings wurde der Effekt des Ausschlusses auf die N2-Komponente durch die Gruppenzugehörigkeit moduliert. Auf diesen Befund wird in Abschnitt 3.4 genauer eingegangen.

## 3.2 Die P3-Komponente: Korrelat des Ostrazismuserlebens oder der Wahrscheinlichkeitsverarbeitung?

Wie im vorherigen Abschnitt aufgezeigt wurde, moduliert eine Manipulation, die keinen Einfluss auf das Ausmaß der Bedürfnisbedrohung nach sozialem Ausschluss hat, auch nicht den P3-Effekt. Es konnte außerdem in einer weiteren Studie (Manuskript Nr. 2: Niedeggen, Sarauli, Cacciola & Weschke, 2014) nachgewiesen werden, dass es – verglichen mit einer Einschlusssituation (33 Prozent Ballerhalt) – zu einer Reduktion der P3-Amplitude auf das Ereignis *self* bei sozialem „Übereinschluss“ (46 Prozent Ballerhalt) kommt, einhergehend mit einer erhöhten Befriedigung sozialer Bedürfnisse. Auf diese Studie wird in Abschnitt 3.4 noch einmal detaillierter eingegangen.

**Fragestellung und Methode.** Die bisherigen Ergebnisse legen nahe, dass der P3-Effekt von der Wahrscheinlichkeit eines aufgabenrelevanten Ereignisses abhängt. Dieser Effekt ist seit langem im Rahmen des Oddball-Paradigmas bekannt (Duncan-Johnson & Donchin, 1977; Polich & Margala, 1997), in dem ein seltener Zielreiz (Target) in einer Reihe von Standardreizen (Standard oder Non-Target) präsentiert wird. Das Target löst eine P300 aus, deren Amplitude abhängig von der Reizwahrscheinlichkeit und der Erwartung der Probanden ist (Polich, 2007; Polich & Criado, 2006; Squires, Squires & Hillyard, 1975). Das Cyberball-Paradigma ist den Oddball-Versuchen recht ähnlich, wenn man den Ballerhalt als Zielreiz (auf diesen muss reagiert werden) und den Nicht-Erhalt als Standardreiz (auf diesen muss nicht reagiert werden) versteht.

Fraglich bleibt, ob ein sozialer Kontext einen signifikanten Beitrag zur Veränderung in den P3-Amplituden leistet. Wie bereits in Abschnitt 2 geschildert, konnten Effekte des sozialen Ausschlusses auf die P3-Amplitude nachgewiesen werden (Kawamoto et al., 2013; Themanson et al., 2013), wurden aber nicht im Rahmen des Oddball-Paradigmas oder der Wahrscheinlichkeit der Reize interpretiert. In einem Experiment sollte geklärt werden, ob dem P3-Effekt im Cyberball- und Oddball-Paradigma ein gemeinsamer Prozess zugrunde liegt (Manuskript Nr. 4: Weschke & Niedeggen, submitted).

Als Fragestellung wurde formuliert:

**Ist die P3 ein direktes Korrelat des Ostrazismuserlebens oder besteht dieser Zusammenhang nur indirekt aufgrund der Manipulation der Wahrscheinlichkeit des Ballerhalts?**

Es wurde vermutet, dass sowohl die Amplitude der P3 als auch die Fragebogendaten durch die Manipulation des Ausschlusses beeinflusst werden, aber nicht direkt miteinander in Zusammenhang stehen. Vielmehr sollte die Wahrscheinlichkeit eines aufgabenrelevanten Ereignisses, also des Ballerhalts, sowohl die P3-Amplitude als auch das Level der Bedrohung sozialer Bedürfnisse beeinflussen. Um zu testen, ob der P3-Effekt unabhängig von dem sozialen Setting auftritt, wurden das Cyberball- und das Oddball-Paradigma direkt miteinander verglichen.

Während in Manuskript Nr. 1 der Realitätsgrad der sozialen Situation durch die physische Präsenz der vermeintlichen Mitspieler erhöht wurde (Weschke & Niedeggen, 2013), sollte nun der soziale Kontext vollständig entfernt werden, indem darauf geachtet wurde, dass die Aufgabe von den Probanden nicht als Ballspiel wahrgenommen wird (Gruppe *Oddball*): Den Versuchspersonen ($n$ = 15) wurde gesagt, dass sie eine einfache Reaktionsaufgabe zu bearbeiten haben, in der sie einen „Kreis“ („Ball“ im Cyberball-Paradigma) auf dem Bildschirm zu A oder B bewegen sollen, wenn er sich auf der Position C befindet. Der Bildschirm war identisch zu dem der Gruppe *Presence* in Manuskript Nr. 1 (Weschke & Niedeggen, 2013; siehe Abschnitt 3.1, Abbildung 4.B) und die Wahrscheinlichkeit des aufgabenrelevanten Ergebnisses betrug wie im Cyberball-Paradigma 33 Prozent im ersten und 17 Prozent im zweiten Aufgabenblock. Jeder Block bestand aus 200 Durchgängen. Die Ergebnisse wurden mit der Gruppe *Internet* (Weschke & Niedeggen, 2013; $n$ = 15), also einer Standard-Cyberball-Bedingung, verglichen.

**Zentrale Ergebnisse.** Während die Reduktion des Ballerhalts zu einer erhöhten negativen Stimmung und Bedürfnisbedrohung– zumindest für die Skalen „Zugehörigkeit“, „Selbstwert“ und „Kontrolle“ – in der Cyberball-Gruppe führte, veränderten sich diese Maße durch die Reduktion der Wahrscheinlichkeit des aufgabenrelevanten Reizes in der Oddball-Gruppe nicht. In beiden Gruppen wurden allerdings die gleiche Abfolge von ereigniskorrelierten Potenzialen durch den Zielreiz (Ereignis *self*) ausgelöst (siehe Abbildung 6): Eine parietale N2 (130-210), eine zentro-parietale P3a

(240-300 ms) und eine parietale P3b (300-410 ms). Die N2 wurde nicht durch die Wahrscheinlichkeit des Ballerhalts/des Zielreizes beeinflusst, aber in beiden Gruppen erhöhte sich der P3-Komplex. Damit konnten vorherige EKP-Befunde repliziert werden (Gutz et al., 2011; Weschke & Niedeggen, 2013).

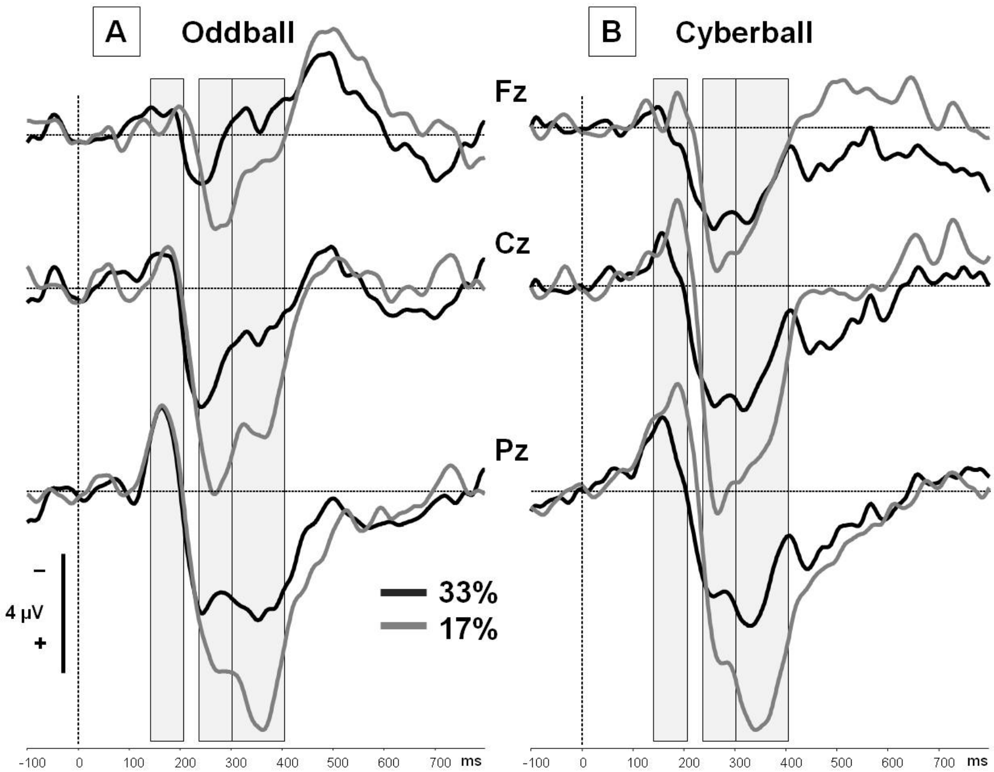


**Abbildung 6:** Grand Averages der experimentellen Gruppen *Oddball* (A) und *Cyberball* (B) in der Inklusionsbedingung (schwarze Linien) und Exklusionsbedingung (graue Linien). Markiert sind die Zeitbereiche der N2 (130-210 ms), P3a (240-300 ms) und P3b (300-410 ms).

**Bedeutung der Befunde.** Die Ergebnisse zeigen, dass die EKP-Befunde unabhängig vom sozialen Kontext oder von der wahrgenommenen Bedürfnisbedrohung sind. Die N2 – unbeeinflusst von der Wahrscheinlichkeit des Zielreizes – spiegelt die Aufgabenrelevanz wider (Bocquillon et al., 2014), wie auch schon von Gutz et al. (2011) für das Cyberball-Paradigma vorgeschlagen wurde. Der P3-Effekt trat unabhängig von der Bedrohung der sozialen Bedürfnisse auf und kann damit nicht als direktes Korrelat des Ausschlussempfindens interpretiert werden. Vielmehr wurde die Amplitude des P3-Komplexes sowohl im Cyberball- als auch im Oddball-Paradigma von der Wahrscheinlichkeit eines aufgabenrelevanten Reizes beeinflusst. Damit ist fraglich, ob diese Komponente kritisch für die Aktivierung eines neuronalen Alarmsystems für sozialen Ausschluss ist.

## 3.3 Erwartungsverletzung als Wirkmechanismus für Erleben und Verarbeitung des sozialen Ausschlusses?

**Fragestellung und Methode.** Die bisherigen Ergebnisse konnten also zeigen, dass die Amplitude der P3, ausgelöst durch den Ballerhalt der Versuchsperson (Ereignis *self*), von der Wahrscheinlichkeit des Ballerhalts abhängig war, unabhängig vom sozialen Kontext oder der Glaubwürdigkeit der Situation. Die P3-Komponente wird allerdings nicht nur von der subjektiven Wahrscheinlichkeit, sondern auch von der Erwartung auf ein Ereignis beeinflusst (Donchin, 1981; Duncan-Johnson & Donchin, 1977), die sich aufgrund von Vorerfahrungen aufbaut. Auch die Detektion von sozialem Ausschluss wurde in einem theoretischen Modell mit der Erwartungsverletzung in Zusammenhang gebracht (Kerr & Levine, 2008).

In einer Studie (Manuskript Nr. 3: Weschke & Niedeggen, 2015) sollten zwei Faktoren, die üblicherweise in der Forschung zu sozialem Ausschluss konfundiert sind, getrennt untersucht werden: Die Wahrscheinlichkeit und die Erwartung des Ballerhalts.

Damit konnten folgende Fragestellungen untersucht werden:

**Welcher Mechanismus ist für die Effekte auf Fragebogenebene (Ausschlussempfinden) und elektrophysiologischer Ebene (P3-Komplex) verantwortlich? Ist es nur die reine Wahrscheinlichkeit des Ballerhalts?**

In den vorherigen Experimenten der Dissertation wurde ein sozialer Einschluss immer durch 33 Prozent Ballerhalt definiert und ein (partieller) Ausschluss durch 17 Prozent. Darauf aufbauend wurde ein Experiment so designt, dass ein Ballerhalt von 17 Prozent nicht notwendigerweise als Ausschluss wahrgenommen wird. Das wurde durch die Erhöhung der Anzahl der Mitspieler erreicht (siehe Abbildung 7). Wie in den vorherigen Studien gab es zwei Spielblöcke, in diesem Fall mit jeweils 300 Ballwürfen, in denen die Wahrscheinlichkeit des Ballerhalts 33 Prozent im ersten und 17 Prozent im zweiten Block betrug. Die Gruppe *Exclusion* ($n$ = 15) diente als Standardbedingung, während in einer zweiten Gruppe (*Expectancy-control*, $n$ = 15) die Anzahl der Mitspieler im zweiten Block von zwei auf fünf erhöht wurde. Eine Ballerhaltenswahrscheinlichkeit von 17 Prozent entsprach also immer noch einem fairen Spiel.

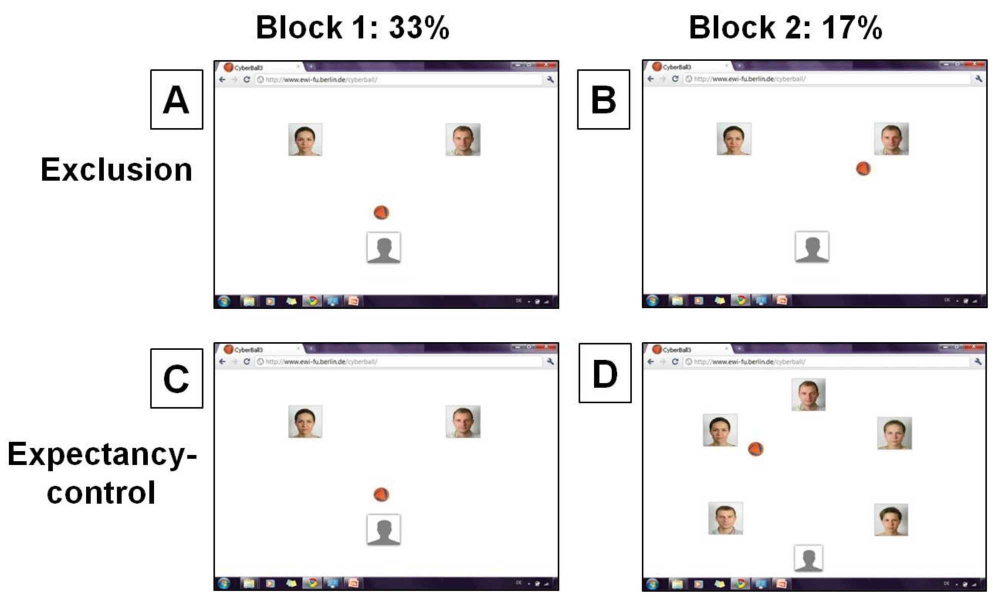


**Abbildung 7:** Darstellung der Bildschirme der beiden experimentellen Gruppen *Exclusion* (A,B) und *Expectancy-control* (C,D). In beiden Gruppen betrug die Wahrscheinlichkeit des Ballerhalt im ersten Block (A,C) 33 und im zweiten Block (B,D) 17 Prozent. In der Gruppe *Expectancy-control* wurde die Anzahl der Mitspieler vom ersten auf den zweiten Block von zwei auf fünf erhöht.

Als Erweiterung zu den bisherigen EKP-Analysen sollte nicht nur das Ereignis, dass die Versuchsperson selbst den Ball bekommen hat (Ereignis *self*), sondern auch die Verarbeitung des direkten Ausschlusses, also der Situation, dass einer der anderen Mitspieler den Ball erhalten hat (Ereignis *other*), ausgewertet werden. Diese Erweiterung war aus zwei Gründen notwendig: Zum einen entspricht der Ballerhalt der Mitspieler den eigentlichen Ausschluss-Ereignissen, zum anderen konnte so auf die Ergebnisse anderer Arbeitsgruppen eingegangen werden, die sich in der Regel auf eben diese Ausschlussereignisse konzentriert hatten. Wie schon oben geschildert, wurden die N2- und die P3-Komponente mit dem Erleben und der Verarbeitung sozialen Ausschlusses in Zusammenhang gebracht, aber nicht im Rahmen des Oddball-Paradigmas interpretiert (Kawamoto et al., 2013; Themanson et al., 2013). Dabei hängt die Amplitude der P3 auch von der Wahrscheinlichkeit der Non-Targets ab (Katayama & Polich, 1996). Die EKP-Analysen konzentrierten sich daher auf die erwartungssensitive parietale P3 (P3b). Es wurde vermutet, dass die Reduktion des Ballerhalts nur in der Gruppe *Exclusion* zu einer Erhöhung der P3b-Amplitude auf das Ereignis *self* führen würde. Für die P3b als Reaktion auf den Ballerhalt der Mitspieler (Ereignis *other*) wurde ein gegenläufiger Effekt erwartet, also eine Reduktion der P3b im Ausschluss, verglichen mit dem Einschluss.

**Zentrale Ergebnisse.** Die Ergebnisse zeigten, dass eine Reduktion des Ballerhalts nur dann zu einem Ausschlussgefühl führte, wenn die Erwartung einer Spielbeteiligung verletzt wurde (Gruppe *Exclusion*). In der Gruppe *Expectancy-control* wurde offensichtlich die Erwartungshaltung für den Ballerhalt an die erhöhte Anzahl von Mitspielern angepasst und daher die vier fundamentalen sozialen Bedürfnisse nicht bedroht. Analog kam es zu keiner Modulation der P3b-Amplituden auf die Ereignisse *self* und *other* (siehe Abbildung 8). Für die Gruppe *Exclusion* konnte gezeigt werden, dass die Reduktion der Wahrscheinlichkeit des Ballerhalts der Versuchsperson (Ereignis *self*) zu erhöhten P3b-Amplituden auf dieses Ereignis führte. Im Einklang mit der erhöhten Wahrscheinlichkeit des Ereignisses *other* während des Ausschlusses war die P3b-Amplitude auf dieses Ereignis verglichen mit dem Einschlussblock reduziert.

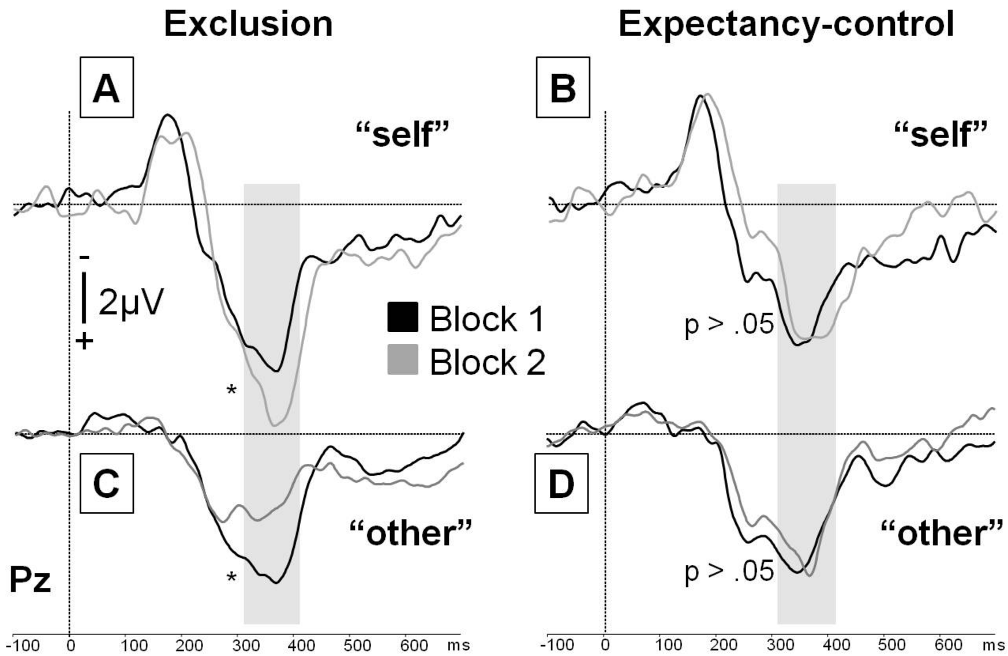


**Abbildung 8:** Grand Averages der experimentellen Gruppen *Exclusion* (A,C) und *Expectancy-control* (B,D) im ersten (schwarze Linien) und zweiten Block (graue Linien) des Spiels für das Ereignis „Ballerhalt der Versuchsperson" („self": A,B) und „Ballerhalt eines Mitspielers" („other": C,D). Markiert ist der Zeitbereiche der P3b.

Die Analysen konzentrierten sich zwar auf die P3b-Komponente, aber die Grand Averages zeigten auch eine Replikation der vorherigen Befunde bezüglich der N2: Diese war nur nach dem Ereignis *self* sichtbar und ihre Amplitude wurde durch Modulationen der Wahrscheinlichkeit oder der Erwartung auf diesen Reiz nicht beeinflusst. Durch die Ereignisse *other* wurde diese Komponente nicht ausgelöst, was noch einmal den Bezug dieser Komponente zur Aufgabenrelevanz verdeutlicht (vgl. Gutz et al., 2011).

**Bedeutung der Befunde.** Die Ergebnisse sind im Einklang mit früheren Cyberball-Studien (Kawamoto et al., 2013; Themanson et al., 2013), sollten aber im Rahmen von Erwartungsverletzungen interpretiert werden. Die P3b-Komponente wird als ein Korrelat kontrollierter Informationsverarbeitung angesehen (Polich, 2007), weshalb die gefundenen Effekte kein „präkognitives“ neuronales Alarmsystems für sozialen Ausschluss widerspiegeln können. Auch fMRT-Daten konnten zeigen, dass die Regionen, die durch sozialen Ausschluss aktiviert werden, auf Erwartungsverletzungen reagieren (Somerville, Heatherton & Kelley, 2006). Die Ergebnisse passen sehr gut zu einem kognitionspsychologischen Modell, das davon ausgeht, dass Inkonsistenzen bzw. Abweichungen von der momentanen Erwartungshaltung unabhängig von der Komplexität der Reize von einem gemeinsamen neuronalen Netzwerk detektiert werden (Proulx, Inzlicht & Harmon-Jones, 2012).

Die Befunde legen nahe, dass auch der Selbstbericht der Versuchspersonen von der Erwartung für sozialen Ein- oder Ausschluss abhängt (vgl. auch Kerr & Levine, 2008), die sich wiederum an die Anzahl der Mitspieler anpasst. Obwohl in beiden Gruppen die Reduktion des Ballerhalts wahrgenommen wurde, führte diese nicht zu einer Bedrohung der sozialen Bedürfnisse, wenn die Anzahl der Mitspieler erhöht wurde.

## 3.4 Können weitere Prozesse identifiziert werden, die an der Verarbeitung von sozialem Ein- oder Ausschluss beteiligt sind?

Da die EKP-Befundlage – verglichen mit der Zahl der fMRT-Studien – noch sehr spärlich ist, wurde explorativ die Fragestellung formuliert, ob weitere Prozesse – neben den Effekten auf der Ebene der P3 – identifiziert werden können, die an der Verarbeitung von sozialem Ein- oder Ausschluss beteiligt sind. In zwei Experimenten wurde eine Komponente nachgewiesen, die in spezifischen Situationen nach dem Ballerhalt der Versuchsperson (Ereignis *self*) auftrat (Weschke & Niedeggen, 2013;

Niedeggen et al., 2014). Auf die Resultate auf Fragebogenebene und auf der Ebene der P3 wurde weiter oben (Abschnitte 3.1 und 3.2) eingegangen. Nun soll ein weiterer Prozess beschrieben werden, der sich etwa im zeitlichen Bereich der N2 nachweisen ließ und unabhängig von dem P3-Effekt auftrat.

In Manuskript Nr. 1 (Weschke & Niedeggen, 2013) wurde die Glaubwürdigkeit des sozialen Settings durch die Anwesenheit der vermeintlichen Mitspieler manipuliert (siehe Abschnitt 3.1). In der Gruppe *Presence* wurde im Zeitbereich der N2-Komponente (130-210 ms nach Ballerhalt) fronto-zentral eine signifikante Amplitudenreduktion im Ausschluss verglichen mit dem Einschluss nachgewiesen. Dieser Effekt trat in der Gruppe *Internet* nicht auf (siehe Abbildung 5).

Da frühere Befunde zeigten, dass eine Amplitudenreduktion der N2 nach angenehmen Reizen in einem emotionalen Oddball-Paradigma auch die Höhe der darauffolgenden P300 beeinflusst (Mardaga & Hansenne, 2009), wurde vorgeschlagen, dass der selektive Effekt im Zeitbereich der N2 nicht durch eine Amplitudenreduktion dieser Komponente hervorgerufen wurde, sondern durch eine Überlagerung einer fronto-zentralen Positivierung (P2). Das legte auch die visuelle Inspektion der Grand Averages nahe (siehe Abbildung 5.B). Die P2-Komponente wurde in vorherigen Studien mit der Verarbeitung von unerwarteten Belohnungen in Verbindung gebracht (Holroyd, Krigolson & Lee, 2011; Potts, Martin, Burton & Montague, 2006). In unserer Studie könnte der Ballerhalt als eine (soziale) Belohnung angesehen werden. Diese ist möglicherweise von höherer Salienz, wenn sie 1. während einer Ausschlusssituation, also unerwartet, auftritt und/oder 2. wenn sie einen sozialen Charakter hat, weil der Interaktionspartner als menschlich angesehen wird.

In Manuskript Nr. 2 (Niedeggen et al., 2014) wurde nicht sozialer Ausschluss, sondern sozialer „Übereinschluss“ mit einer Einschlusssituation verglichen (siehe auch Abschnitt 3.2). An dem Experiment nahmen 40 Probanden teil, wovon die eine Hälfte erst die Bedingung „Übereinschluss“ (46 Prozent Ballerhalt) und dann die Bedingung „Einschluss“ (33 Prozent Ballerhalt) durchlief, und die andere Hälfte mit dem Einschluss begann. In beiden Blöcken gab es jeweils 200 Ballwürfe. Eine erhöhte frontale P2-Komponente (150-210 ms nach Ballerhalt) zeigte sich während des Übereinschlusses, allerdings nur in der Gruppe, die mit dem Einschluss begonnen hatte (siehe Abbildung 9).

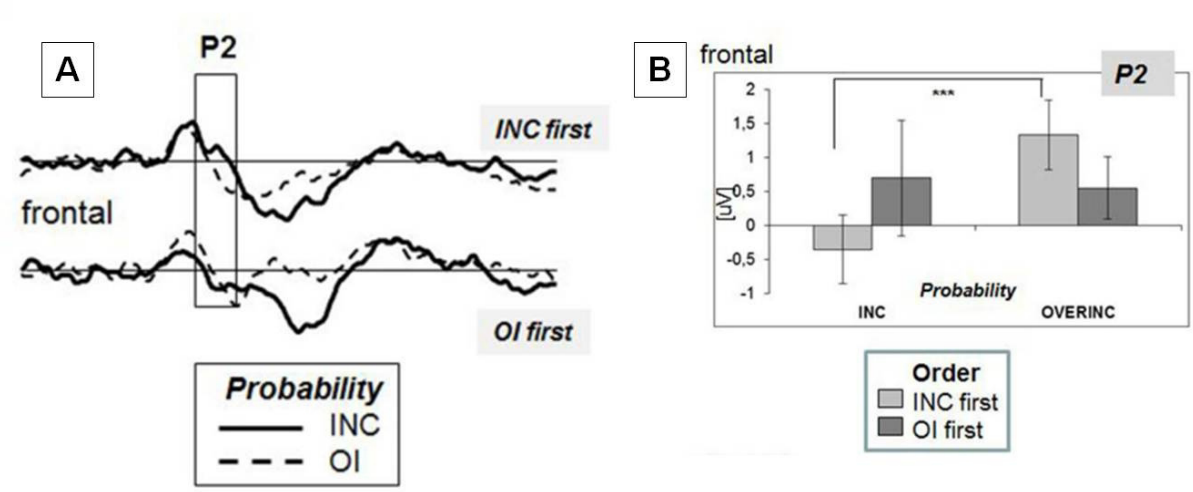


**Abbildung 9:** (A) Grand Averages der experimentellen Gruppen „Einschluss zuerst“ (INC first) und „Übereinschluss zuerst“ (OI first) in den Bedingungen „Einschluss“ (durchgezogene Linien) und „Übereinschluss“ (gestrichelte Linien). (B) Mittlere Amplituden der frontalen P2-Komponente (Fehlerbalken repräsentieren die Standardabweichungen). Eine signifikante Erhöhung der P2 während des Übereinschlusses zeigte sich nur in der Gruppe „Einschluss zuerst“ (Abbildung modifiziert nach Niedeggen et al., 2014, S.6).

Auch in dieser Studie könnte die P2 als Korrelat der (sozialen) Belohnungsverarbeitung angesehen werden (vgl. Holroyd et al., 2011; Potts et al., 2006). Es wurde vorgeschlagen, dass der Übereinschluss nur dann als besondere soziale Belohnung angesehen wurde, wenn es vorher eine Erfahrung des Einschlusses gab, durch die eine bestimmte Erwartungshaltung bezüglich des Ballerhalts aufgebaut werden konnte.

Der Übereinschluss könnte dann als eine Situation angesehen werden, die „besser als erwartet" ist, was sich in der erhöhten P2-Amplitude zeigt.

Die geschilderten Effekte im Bereich der N2/P2 sind insofern von besonderer Relevanz, weil sie zeigen, dass elektrophysiologische Daten als Online-Maß in der Lage sind, auch solche Prozesse zu erfassen, die nicht mithilfe eines retrospektiven Selbstberichts (in Form des NTQ) erhoben werden können. Ob die P2-Komponente allerdings tatsächlich ein Korrelat der sozialen Belohnungsverarbeitung im Cyberball-Paradigma ist, muss in zukünftigen Studien weiter abgesichert werden (siehe Abschnitt 4).

# 4. Diskussion und Ausblick

In der vorliegenden Arbeit wurde untersucht, welche elektrophysiologischen Korrelate von sozialem Ein- und Ausschluss im Cyberball-Paradigma identifiziert werden können und welche kognitiven oder emotionalen Mechanismen für die gefundenen Effekte verantwortlich sind. Mithilfe eines direkten Vergleichs konnte nachgewiesen werden, dass im Cyberball- und Oddball-Paradigma ähnliche Prozesse aktiviert werden. Die elektrophysiologischen Effekte, die während des Cyberball-Spiels auftraten, waren weitestgehend unabhängig davon, ob eine Situation als sozial wahrgenommen wurde oder nicht. Durch eine experimentelle Trennung der Wahrscheinlichkeit des Ballerhalts von der Erwartung auf den Ballerhalt konnte gezeigt werden, dass die Verletzung von Erwartungshaltungen sowohl die Effekte auf der Ebene der P3 als auch das wahrgenommene Ausschlussgefühl im Cyberball-Paradigma erklären kann.

Welche Implikationen ergeben sich für das von Williams und Kollegen (z.B. Williams, 2007; Williams & Zadro, 2005) postulierte Need-Threat-Modell? Für die Gültigkeit des Modells spricht, dass die Glaubwürdigkeit der sozialen Situation keinen Einfluss auf die Bedrohung der fundamentalen sozialen Bedürfnisse hatte (Weschke & Niedeggen, 2013; vgl. auch Zadro et al., 2004). Allerdings impliziert ein (neuronales) Alarmsystem für sozialen Ausschluss eine Unidirektionalität (Kawamoto et al., 2012; Williams, 2007), also eine spezifische Aktivierung während einer Ausschlusssituation. Die Befunde (Niedeggen et al., 2014; Weschke & Niedeggen, 2013) konnten jedoch zeigen, dass sowohl die Befriedigung der fundamentalen sozialen Bedürfnisse als auch die P3-Amplitude eher einem linearen Kontinuum von Übereinschluss zu Einschluss zu partiellem Ausschluss folgen (vgl. auch Williams et al., 2000).

Mithilfe der Analyse von ereigniskorrelierten Potentialen, die eine hohe zeitliche Auflösung bieten, sollten mögliche elektrophysiologische Korrelate eines neuronalen

Frühwarnsystems für Ostrazismus nachgewiesen werden. Als einzige Komponente, die reliabel auf sozialen Ein- oder Ausschluss reagiert, konnte die P3-Komponente identifiziert werden. Vergleichbare Effekte gab es auch in anderen Studien (Kawamoto et al., 2013; Themanson et al., 2013) und wurden im Sinne eines möglicherweise exklusionsspezifischen Alarmsystems interpretiert. Wir konnten Korrelationen zwischen sozialem Schmerz und der P3-Amplitude (Gutz et al., 2011; Kawamoto et al., 2013) nicht replizieren, sondern vielmehr nachweisen, dass der P3-Effekt unabhängig von einem Ausschlussgefühl war (Weschke & Niedeggen, submitted).

Wir schlagen vor, dass die reliabel nachweisbaren Effekte im Cyberball-Paradigma – also der P3-Effekt und das durch den Selbstbericht erfasste Ausschlussgefühl – durch einen gemeinsamen Mechanismus erklärt werden können, und zwar durch die Erwartungsverletzung (Weschke & Niedeggen, 2015). Das Need-Threat-Modell sollte diese Erkenntnisse berücksichtigen. Sie stellen möglicherweise auch gar keinen Widerspruch zum Modell dar: Die Sozialpsychologie und die Neurowissenschaften benutzen kein gemeinsames Vokabular. Ein Effekt auf der Ebene der P3 wird in der Elektrophysiologie weder als besonders früh noch als „prä-attentiv" oder „präkognitiv" bezeichnet, was anscheinend in der Sozialpsychologie anders gesehen wird. Zumindest auf der begrifflichen Ebene sollte daher die Theorie des „neuronalen präkognitiven Alarmsystems" modifiziert werden. Dann könnten die Resultate der neurophysiologischen Forschung besser in das Modell integriert werden. Ein Ansatz wäre beispielsweise, die Reaktion auf Erwartungsverletzungen als entscheidenden Mechanismus anzusehen. Diese Reaktion könnte den Charakter eines Alarmsystem haben, allerdings nicht eines exklusionsspezifischen. Damit können sowohl Ergebnisse der Sozialpsychologie (Kerr & Levine, 2008) als auch solche der Neurowissenschaften (Proulx et al., 2012; Somerville et al., 2006) integriert werden.

Die vorliegende Arbeit sollte einen Beitrag zur Grundlagenforschung leisten, indem die elektrophysiologischen Korrelate von sozialem Ein- und Ausschluss genauer untersucht und geklärt werden sollte, welche Mechanismen für die gefundenen Effekte verantwortlich sind. Die Befunde können aber auch in der angewandten Psychologie genutzt werden. Dass die Erwartungshaltung bezüglich eines sozialen Ein- oder Ausschlusses einen entscheidenden Einfluss auf den P3-Effekt hat, konnte kürzlich in einer Studie mit klinischen Stichproben bestätigt werden (Gutz, Renneberg, Roepke & Niedeggen, 2015): Personen, bei denen eine Borderline-Persönlichkeitsstörung diagnostiziert wurde, zeigten eine erhöhte P3-Amplitude auf den Ballerhalt bereits während einer Einschlusssituation. Dies korrespondierte mit dem selbstberichteten Ausschlussempfinden – und entscheidender – mit einer erhöhten Erwartungshaltung für sozialen Ausschlusses. Diese Ergebnisse können zu einem besseren Verständnis des Störungsbildes beitragen. Außerdem können sie im Rahmen der Psychoedukation genutzt werden, um Patienten zu verdeutlichen, dass ihre Wahrnehmung von sozialer Zurückweisung während einer sozialen Interaktion möglicherweise nicht der Realität entspricht.

Während die Rolle der P3 im Cyberball-Paradigma durch die durchgeführten Experimente aufgedeckt werden konnte, müssen die Resultate auf der Ebene der P2-Komponente durch weitere Befunde abgesichert werden. Die Ergebnisse legen nahe, dass diese Komponente die Verarbeitung einer unerwarteten sozialen Belohnung widerspiegelt. Ob der sozialen Charakter der Situation das Entscheidende ist, könnte mit einem Setting getestet werden, in dem nur einer der beiden Mitspieler physisch anwesend ist. Damit kann überprüft werden, ob der Ballerhalt von dieser Person verglichen mit einem virtuellen Mitspieler anders verarbeitet wird. Vorstellbar wäre auch den Ballerhalt in einem Experiment monetär zu belohnen, um die Wertigkeit und damit den Belohnungscharakter dieses Reizes zu erhöhen.

Es muss bedacht werden, dass der Effekt auf der Ebene der P2 nur in bestimmten Situation auftrat. Diese Komponente, auch wenn sie möglicherweise einen spezifisch „sozialen“ Charakter hat, kann also nicht als Korrelat eines in allen Ausschlusssituationen aktivierten neuronalen Alarmsystems angesehen werden. Zwar stimmt die frontale Topographie der P2 eher mit anderen Befunden überein, die ein Alarmsystem in medio-frontalen Arealen vermuten (Eisenberger et al., 2003; Themanson et al., 2013), aber sie spiegelt keine klassische Komponente der Konfliktverarbeitung wider. Die in diesem Zeitbereich gefundene N2 wiederum wies ein parietales Maximum auf (Weschke & Niedeggen, submitted) und kann daher als Korrelat der Zielreiz- und nicht der Konfliktverarbeitung angesehen werden (Folstein & Van Petten, 2008).

Die Ergebnisse der vorliegenden Arbeit sprechen dafür, dass die elektrophysiologischen Korrelate von sozialen Ein- und Ausschluss in einem breiteren Kontext interpretiert und mit anderen Verarbeitungsprozessen wie der Aufgabenrelevanz oder der Wahrnehmung von Erwartungsverletzungen in Zusammenhang gebracht werden müssen. Allerdings kann in der Zukunft mit verbesserten Methoden und damit einhergehenden feineren Analysen möglicherweise auch ein System im Gehirn identifiziert werden, das exklusiv für die Verarbeitung von sozialem Ein- oder Ausschluss zuständig ist. Die rasante Entwicklung in den Neurowissenschaften zeigt, wie schnell Befunde überholt sein können. Die prominente „Social Pain/Physical Pain Overlap"-Theorie (Eisenberger & Lieberman, 2005) konnte mit genaueren Methoden der Bildgebung inzwischen teilweise widerlegt werden (Woo et al., 2014), denn nun lassen die Verfahren die Bestimmung von Konnektivitäten zwischen Regionen als auch von differenziellen Aktivierungen innerhalb einer Region zu, was vor über zehn Jahren, als Eisenberger und Kollegen ihre ersten Arbeiten veröffentlicht haben (z.B. Eisenberger et al., 2003), nur eingeschränkt möglich gewesen ist. Mit feineren Analysenverfahren wird es immer mehr möglich sein, funktionell verbundene oder getrennte Bestandteile neuronaler Netzwerke identifizieren zu können.

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# 6. Originalarbeiten

Die Dissertation basiert auf folgenden Forschungsartikeln:

1. Weschke, S. & Niedeggen, M. (2013). The effect of the physical presence of co-players on perceived ostracism and event-related brain potentials in the cyberball paradigm. *PLoS One, 8*(8). doi: http://dx.doi.org/10.1371/journal.pone.0071928

2. Niedeggen, M., Sarauli, N., Cacciola, S. & Weschke, S. (2014). Are there benefits of social overinclusion? Behavioral and ERP effects in the Cyberball paradigm. *Frontiers in Human Neuroscience, 8*(935). doi: http://dx.doi.org/10.3389/fnhum.2014.00935



3. Weschke, S. & Niedeggen, M. (2015). ERP effects and perceived exclusion in the Cyberball paradigm: correlates of expectancy violation? *Brain Research*, epub ahead of print. doi: http://dx.doi.org/10.1016/j.brainres.2015.07.038 (akzeptiert am 23.07.2015)

4. Weschke, S. & Niedeggen, M. (submitted). Eliminating social context in a Cyberball-like visual oddball task: ERP effects are independent of a feeling of exclusion. *PLoS One*. (eingereicht am 11.08.2015)

## 6.1 The effect of the physical presence of co-players on perceived ostracism and event-related brain potentials in the cyberball paradigm

Sarah Weschke & Michael Niedeggen

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# The Effect of the Physical Presence of Co-Players on Perceived Ostracism and Event-Related Brain Potentials in the Cyberball Paradigm

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## Abstract

The affective and cognitive mechanisms elicited by the experience of social exclusion—or ostracism—have recently been explored using behavioral and neurocognitive methods. Most of the studies took advantage of the Cyberball paradigm, a virtual ball tossing game with presumed co-players connected via the internet. Consistent behavioral findings indicate that exclusion obviously threatens fundamental social needs (belonging, self-esteem, meaningful existence, and control) and lowers mood. In this study, we followed the question whether the credibility of the setting affects the processing of social exclusion. In contrast to a control group (standard Cyberball setup), co-players were physically present in an experimental group. Although the credibility of the virtual ball tossing game was significantly enhanced in the experimental group, self-reported negative mood and need threat were not enhanced compared to the control group. Event-related brain potentials (ERPs), however, indicated a differential processing of social exclusion. The N2 amplitude triggered by occasional ball receptions was significantly reduced in the experimental group. This effect was restricted for an early time range (130–210 ms), and did not extend to the following P3 components. The ERP effect in the N2 time range can be related to a differential social reward processing in ostracism if co-players are physically present. The lack of a corresponding correlate in the behavioral data indicates that some facets of ostracism processing are not covered by questionnaire data.

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## Introduction

Ostracism is defined as "ignoring and excluding individuals or groups by individual or groups" [1]. As a framework to explicate the assumed reflexive and reflective reactions following ostracism, the need-threat model was proposed, stating that four fundamental needs, namely belonging, self-esteem, meaningful existence, and control, are threatened following ostracism [2]. Since belonging to a group is essential for physical and psychological health [3] the painful threat of the fundamental needs is assumed to serve as an early detection system to enhance motivation to reconstitute affiliation to other persons [4]. The mechanisms of perceiving and processing social exclusion have not only been studied using behavioral [1], but also neuroimaging [5,6] and electrophysiological methods [7,8,9]. Both approaches were helpful in localizing the neuronal and cognitive networks involved.

Most of the behavioral and psychophysiological studies took advantage of the Cyberball paradigm [10,11]. Here, participants are told to play a virtual ball tossing game with two – or more – other participants connected via the internet to measure visual imagination capabilities. In fact, the "co-players" are computer-generated and the probability of receiving the ball is experimentally manipulated, i.e. in the exclusion condition the participant hardly ever receives the ball. Despite its artificial character, several studies confirmed that fundamental social needs can be reliably threatened with the Cyberball game [12,13].

Nevertheless, it can be questioned whether the effect of ostracism is independent from the credibility of the paradigm. Although there is evidence that ostracism can even be elicited when the participants knew that they were playing with computer-generated co-players [14], other studies have shown that the conviction of interacting with a computer or another human leads to huge differences in emotions and behavior in tasks [15,16,17]. For example, subjects interacting with a computer described them as behaving according to a design, whereas human beings are perceived as intentionally and rationally acting agents [18]. Moreover, the emotional state was found to be modulated in social exchange paradigms when human players – but not computers – were involved [19].

The studies aforementioned lead to the question of whether an increase of authenticity will change the ostracism effect induced in the Cyberball game. One possible approach is the introduction of co-players who are physically present. The presence of co-players might not only affect the credibility of the experimental situation, but also have an effect on the affective or cognitive processing of social exclusion. It is well known that behavior or perceptional decisions are influenced by the presence of other human beings [20,21], even if they did not directly observe the behavior of the subject [22]. Also, automatic attitudes and spontaneous affective responses can be changed by the presence of other human beings [23,24].

A further question is whether the effect of introducing co-players physically present can be measured by means of a retrospective method. In most of the experimental studies based on the Cyberball paradigm the Need Threat Questionnaire (NTQ) [10] was applied. The NTQ measures the effects of inclusion or exclusion on the perceived level of social need threat (belonging, self-esteem, meaningful existence, and control) and on negative mood. However, the NTQ – like other questionnaires – is applied subsequently to the experience of exclusion induced in the Cyberball game. In this respect, it seems advantageous to adopt an online measurement such as the recording of electrophysiological activity *during* the Cyberball game. Event-related potentials (ERPs) meet the requirements of investigating a pre-cognitive early detection system through its high temporal resolution. Previous studies have shown that ERPs time-locked to the event of not receiving the ball evoke a late prefrontal positivity interpreted as a coping mechanism as a reaction to exclusion, and enhanced N2 and P3 amplitudes [7,9,25].

Since the Cyberball paradigm shares some characteristics of the well-established Oddball paradigm [26], we focused our analysis on the critical event "ball possession" in a previous study [8]. The corresponding ERP probes are related to the subjective stimulus relevance, probability, and expectancy [27,28,29]. The results confirmed that an N2/P3 complex is (a) triggered when the player receives the ball, and (b) significantly enhanced when comparing exclusion (two co-players: 16% ball possession) with inclusion (two co-players: 33% ball possession). Finally, we observed significant correlations between the P3 complex, negative mood and perceived ostracism intensity. The latter confirms our assumption that components in the P3 complex can serve as a valid "online" indicator for ostracism expectancy [8].

These previous results triggered the experimental question whether retrospective reports (NTQ) and/or ERP correlates will be affected if the credibility of the Cyberball game is enhanced. For this reason, we compared the standard design (virtual presence of co-players) with a modified setup (physical presence of two – assumed – co-players). Since there is evidence that the source of exclusion does only have minimal influences on the NTQ data [14], we did not expect that the retrospectively reported experience of ostracism will be affected by the physical presence of co-players. We rather expected an effect on negative mood since a higher credibility of the social setting was found to modulate the affective state [19]. With respect to the ERP components, we assumed that ball possession will trigger a N2/P3 complex, and that specific components will reflect the involvement in the game and the presence of co-players: In the oddball-like setup [8], the N2 amplitude was determined by ball reception irrespective of the social interaction context (inclusion vs. exclusion). Since the component apparently indicates task relevance [30], we did not expect a modulation of this component. The following P3a, however, was enhanced in the exclusion block [8], and appears to reflect the activation of a conflict-based neural alarm system related to activity in the anterior cingulate cortex [31,32]. Since its amplitude was also related to the affective state of the participant [8], we assumed that the P3a can be enhanced by the physical presence of co-players. As for the P3b, a corresponding modulation in amplitude was also observed in the exclusion condition [8]. Comparable to the oddball-design, the increase in amplitude as well as its relation to perceived ostracism was related to a modulation in subjective probability [29]. Since the component is therefore rather related to cognitive processes, such as memory updating or stimulus classification [33], we did not expect a modulation in our experimental setup.

## Materials and Methods

### Participants

The procedure was approved by the local ethics committee at the FU Berlin. Thirty-six healthy subjects participated in the experiment. Due to a high number of artifacts in the EEG, six participants had to be excluded, leaving 30 for analyses. The participants had self-reportedly no history of psychiatric or neurological disorders and were not taking medication affecting the central nervous system. They were recruited in the university environment and gave their written consent for participating. The subjects were randomly assigned to one of the experimental groups (Internet $n = 15$, 7 female, mean age $= 24.7$ years; Physical Presence $n = 15$, 10 female, mean age $= 22.5$ years). Since a cover story was required to induce the experimental effect, participants were informed about the experimental technique and aiming of the study afterwards. Participants got credit points for their studies.

### Task and Design

E-Prime 2 (Psychology Software Tools, Inc.) was used to present standardized instructions, the Cyberball game and to trigger EEG recording. All participants were told that they took part in a study testing visual imagination capabilities. To keep up this cover story, all participants first completed a short questionnaire (Vividness of Visual Imagery Questionnaire) about visual imagination ability [34].

Setup for the group *Internet* followed the established Cyberball design [8]: Participants were told that they would play a ball tossing game with two other co-players connected via internet. In contrast, participants assigned to the group *Presence* ought to believe they were playing with the two other co-players present in the same room, who were actually confederates of the experimenter (see Figure 1). To enhance plausibility, the confederates also had electrodes fixed on their scalps. They greeted each other, but were told not to talk or interact in another way during the experiment. Earlier, the confederates were requested not to react on possible comments of the participant during the game.

Following the instructions and a short training introduction, all participants went through two blocks of the Cyberball game. Each block consisted of 200 ball throws and lasted about 7 minutes. In the block *Inclusion*, the participant received the ball in about one third of all ball throws (33 percent); in the following block *Exclusion*, the probability of getting the ball was marked down to 17 percent. The partial exclusion was necessary in order to record the ERP correlate of the event "ball possession", and we have shown previously that partial exclusion is also sufficient to induce a significant effect of ostracism [8].

After the exclusion block, two NTQ questionnaires were handed out. The subjects were told to retrospectively fill out the questionnaires, the first one regarding the first block, and the second one regarding the second block. To make the separation of the two experimental blocks less difficult, one part of the ball tossing game had to be imagined in the meadow and the other game on a beach (the order was counterbalanced across subjects). As already indicated in our previous study [8], the NTQ can reliably differentiate between the *Inclusion* and *Exclusion* condition, even if ratings on the first block are to be delivered with a temporal delay.

Participants were also asked to rate if they believed that their co-players were computer-generated. After completing all questionnaires, the subjects were informed about the real aim of the study. In the group *Presence* it was made sure that participants were informed about the scripted behavior of the two co-players.

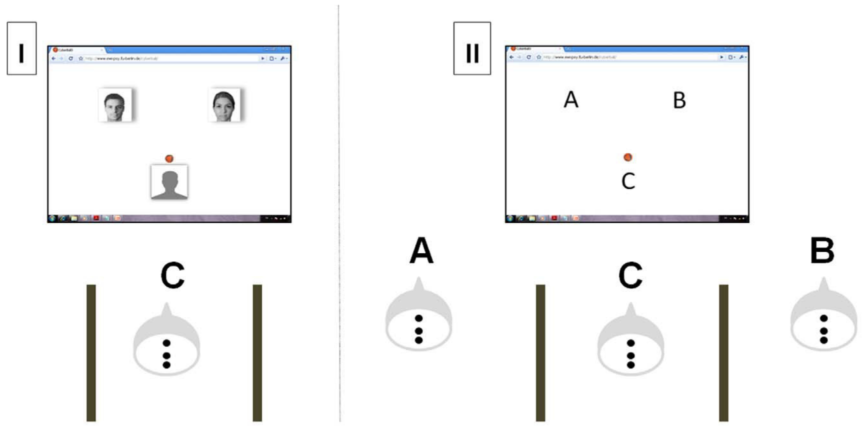


**Figure 1. Experimental setting for the *Internet* (I) and *Presence* (II) condition.** The real participant was always sitting at position C. In the *Internet* group, the two "co-players" were depicted by two photographs. In the *Presence* group, the confederates "A" and "B" pretended to be involved in the ball tossing game, which was actually possible only in 15 training trials at the beginning of the game. Please note that the photographs of co-players depicted do not refer to real persons, but are morphs of different portraits.
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### EEG Recording and data analysis

**EEG data.** EEG data were recorded from 3 active electrode positions (Fz, Cz, Pz). Previous experiments had shown that these positions are highly sensitive to record the components of interest [8]. Ag/AgCl skin electrodes were fixed on the scalp with EC2 Electrode Cream (Grass Technologies). Active electrodes (impedance <10 kΩ) were referenced to linked earlobes (< 5 kΩ), with AFz serving as ground. Vertical and horizontal electrooculogram (EOG) were also recorded to control for ocular artefacts (< 20 kΩ). Biosignals were recorded continuously with EEG BioAmplifiers and Psylab recording software (Contact Precision Instruments, London), then analyzed with BrainVision Analyzer 2 (Brain Products GmbH, Germany). Offline, data were band-pass filtered (0.3 to 30 Hz) and notch filtered (50 Hz). EEG segments were created (–100 to 800 ms after the participant received the ball) according to the condition *Inclusion* or *Exclusion* and baseline-corrected (–100 to 0 ms). Subsequently, a semiautomatic artifact rejection was performed, eliminating segments containing eye blinks, muscular artifacts or high alpha activity. Since there were more segments for ball possession in the condition *Inclusion* by definition, the number of EEG segments was randomly chosen to adjust it to the number of segments obtained in the condition *Exclusion*. Averages and grand averages were calculated, separately for the two experimental groups, conditions and three electrode positions. Grand averages revealed distinctive components in three consecutive time ranges: 130 to 210 ms (N2), 240 to 300 ms (P3a), and 300 to 410 ms (P3b). Mean amplitudes in these time windows were exported and analyzed using SPSS (version 19, IBM). Repeated measures ANOVAs were calculated including the between-subject factor "group assignment" (*Internet* vs. *Presence*) and the within-subject factors "condition" (*Inclusion* vs. *Exclusion*) and "electrode position" (Fz vs. Cz vs. Pz). Degrees of freedom and *p*-values were corrected according to Greenhouse-Geisser, if indicated, and corrected *p*-values will be reported in the following.

**Behavioral data.** For each participant, data of the NTQ and additional questions were read in SPSS (version 19, IBM) and NTQ scales belonging, self-esteem, meaningful existence and control, and an additional scale included in the NTQ measuring negative mood were computed (all items were rated on a 1 to 5 Likert scale, with NTQ scales having a potential range between 1 and 5 and negative mood between 4 and 20). The data were analyzed running a repeated measures ANOVA including the between-subject factor "group" (*Internet* vs. *Presence*) and the within-subject factor "condition" (*Inclusion* vs. *Exclusion*). To assess the conviction regarding the cover story that the subjects were playing with other human beings the participants finally rated the statement "the co-players were computer-generated" on a 1 to 5 Likert scale after completing the NTQ (see Table 1), also analyzed by a repeated measures ANOVA including the between-subject factor "group" and the within-subject factor "condition" and one-way comparisons within each condition.

## Results

### Behavioral Data

Behavioral data (see Table 1) showed that the presence of two supposed co-players led to a reduced acceptance of the item "co-players were computer-generated" compared to the group *Internet*. This was confirmed by a main effect of the factor "group" in an ANOVA, $F(1,28) = 31.608$, $p<.001$, $\eta^2 = .530$. In addition, a main effect of the factor "condition", $F(1,28) = 8.624$, $p = .007$, $\eta^2 = .235$, showed the assumption to interact with a computer was increased during exclusion. This effect was not modulated by group membership (interaction $F(1,28) = 1.703$, $p = .202$). In one-way comparisons for *Inclusion* and *Exclusion*, respectively, the group difference was also confirmed (*Internet* vs. *Presence*: Inclusion: $F(1,28) = 35.456$, $p<.001$, $\eta^2 = .559$; Exclusion: $F(1,28) = 15.138$, $p = .001$, $\eta^2 = .351$).

In each NTQ scale, the expected decrease in the condition *Exclusion* as compared to *Inclusion* regarding the four fundamental needs was obtained, as well as a decrease in the estimation of ball possession (see Table 1). The analysis of the NTQ scales confirmed the expected significant reduction for the scales "belonging", $F(1,28) = 35.162$, $p<.001$, $\eta^2 = .557$, "self esteem", $F(1,28) = 7.377$, $p = .011$, $\eta^2 = .209$, "meaningful existence", $F(1,28) = 12.782$, $p = .001$, $\eta^2 = .313$, and "control", $F(1,28) = 12.782$, $p<.001$, $\eta^2 = .378$. Moreover, the data indicated a significant increase in "negative mood", $F(1,28) = 28.595$, $p<.001$, $\eta^2 = .505$. There was neither a main effect of group assignment (*p*-value $\geq .215$ for each of the four NTQ scales and negative mood) nor an interaction of the factors "condition" and "group" (*p*-value $\geq .180$ for each NTQ scale and negative mood) obtained.

In addition, estimation of ball possession by the participants (see Table 1) differed significantly between *Inclusion* and *Exclusion*,

**Table 1.** Behavioral data

| | Internet | | Presence | |
|---|---|---|---|---|
| **NTQ Scale** | **Inclusion** | **Exclusion** | **Inclusion** | **Exclusion** |
| belonging | 3.8000 (0.5746) | 2.5333 (0.9241) | 4.1556 (0.6769) | 2.6667 (1.1055) |
| self esteem | 3.6000 (0.6068) | 3.1778 (0.5019) | 3.4667 (0.6016) | 3.2222 (0.7834) |
| meaningful existence | 4.2667 (0.8281) | 3.6000 (1.0925) | 4.3111 (1.0348) | 3.2000 (1.1464) |
| control | 2.3111 (0.6954) | 1.6667 (0.7346) | 2.0667 (0.7684) | 1.4000 (0.4216) |
| negative mood | 8.5333 (2.5317) | 12.6000 (2.7464) | 8.5000 (2.9641) | 11.1333 (3.4355) |
| Estimated percentage ball possession | 30.5333 (10.3776) | 12.9333 (5.4703) | 28.2000 (6.6030) | 15.2667 (7.5448) |
| Item "Co-players were computer-generated." | 3.7333 (1.1629) | 4.0667 (1.0328) | 1.5333 (0.8338) | 2.4000 (1.2984) |

Behavioral results of the *Internet* and *Presence* group for the *Inclusion* and *Exclusion* blocks are depicted. Mean values and standard deviations (in brackets) are presented.
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$F(1,28) = 68.875$, $p<.001$, $\eta^2 = .711$, independently of group membership (main effect group: $F(1,28) = 1.609$, $p = .215$; interaction: $F(1,28) < 1$).

## ERP Data

The grand-averaged ERPs evoked by the event "ball possession" are depicted in Figure 2. Three time ranges were exported for further analyses: The N2 range (130 to 210 ms) was marked by a negative peak at about 180 ms, the P3a (240 to 300 ms) by a fronto-central positivity at about 260 ms, and the P3b (300 to 410 ms) by a late parietal positivity peaking at about 350 ms. The mean amplitudes and standard deviations for the three components are presented in Table 2.

**N2 (130–210 ms).** In both groups, the N2 component was clearly visible in the conditions *Inclusion* and *Exclusion*, mostly pronounced at parietal leads (main effect of electrode position, $F(2,56) = 29.373$, $p<.001$, $\eta^2 = .512$). As depicted in Figure 2, the component was reduced in the group *Presence* during exclusion, whereas a contrary effect was observed in the group *Internet*. This was confirmed by an interaction of the factors "group" and "condition", $F(1,28) = 6.648$, $p = .015$, $\eta^2 = .192$. Post-hoc comparison within each group confirmed a significant reduction of the component in the group *Presence*, $F(1,14) = 7.031$, $p = .019$, $\eta^2 = .334$, most pronounced at fronto-central leads. In contrast, no significant modulation in the group *Internet*, $F(1,14) = 1.603$, $p = .226$, was found. The effect cannot be attributed to inherent differences between groups during inclusion, since the corresponding post-hoc comparisons did not indicate any differences between groups in the condition *Inclusion* ($p$-value $\geq .477$ for each electrode).

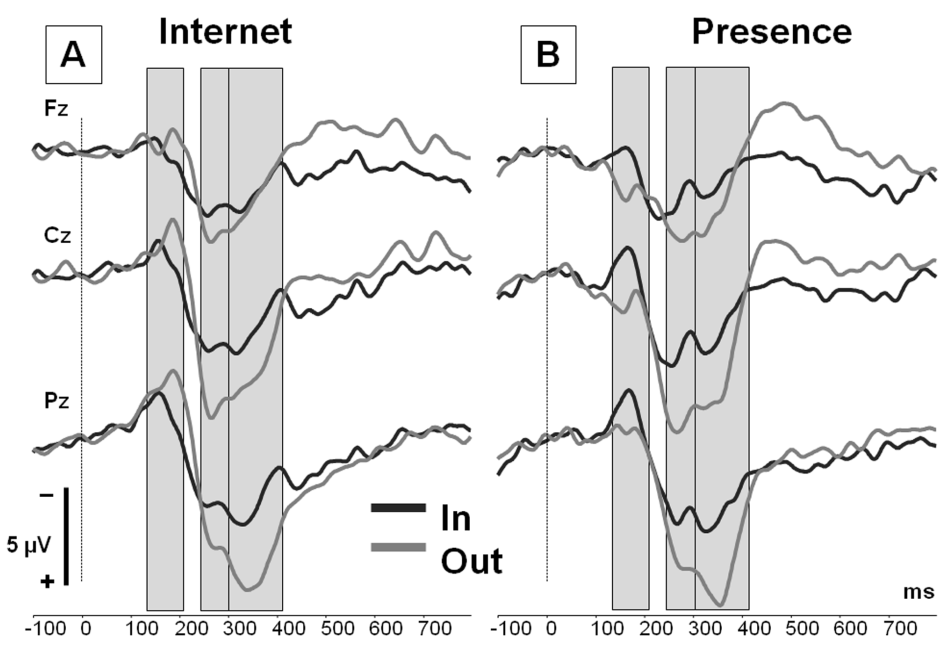


**Figure 2. ERP data.** Grand-averaged ERPs for the event "ball possession of the participant" in the *Inclusion* (dark grey) and *Exclusion* condition (light grey) recorded from the electrode positions Fz, Cz and Pz. Three time windows are highlighted: 130–210 ms (N2), 240–300 ms (P3a), and 300–410 ms (P3b). (A) Superimposition of the ERP traces in the group *Internet*: Co-players are assumed to be connected via internet. (B) Superimposition of the ERP traces in the group *Presence*: Co-players are physically present in the lab.
doi:10.1371/journal.pone.0071928.g002

**Table 2.** Electrophysiological data

| ERP component | Electrode position | Internet | | Presence | |
|---|---|---|---|---|---|
| | | Inclusion | Exclusion | Inclusion | Exclusion |
| N2 | Fz | 0.0994 (2.1858) | −0.5316 (3.2778) | 0.6305 (1.8439) | 2.1040 (2.7702) |
| | Cz | −0.8220 (2.5238) | −1.8387 (3.7477) | −0.3012 (2.3122) | 1.6751 (3.5746) |
| | Pz | −1.5536 (2.4044) | −2.9526 (3.4894) | −1.5166 (2.1295) | −0.3623 (3.7714) |
| P3a | Fz | 3.1338 (3.2622) | 4.3682 (5.0819) | 2.6029 (3.1952) | 4.5014 (3.6478) |
| | Cz | 3.8761 (4.6757) | 6.9462 (5.5924) | 4.1932 (4.1449) | 7.9977 (2.5751) |
| | Pz | 3.5246 (4.0801) | 5.3526 (4.2705) | 4.0239 (3.2034) | 6.2860 (3.0721) |
| P3b | Fz | 2.2193 (3.2225) | 2.5030 (2.8470) | 1.5775 (2.8913) | 2.7261 (3.7795) |
| | Cz | 2.8520 (3.9656) | 5.2044 (2.3687) | 2.9440 (2.8710) | 5.5544 (3.2789) |
| | Pz | 3.3914 (3.1557) | 7.1318 (3.2258) | 3.9171 (3.3838) | 7.3046 (2.9446) |

Mean values of ERP components of the *Internet* and *Presence* group for the *Inclusion* and *Exclusion* blocks are depicted. ERPs were recorded from Fz, Cz and Pz. Mean values and standard deviations (in brackets) in microvolt are presented for three distinct time frames (N2: 130–210 ms, P3a: 240–300 ms, P3b: 300–410 ms).
doi:10.1371/journal.pone.0071928.t002

**P3a (240–300ms).** Receiving the ball evoked an early positivity most prominent at Cz (main effect of electrode: $F(2,56) = 11.498$, $p<.001$, $\eta^2 = .291$) and more pronounced in the exclusion condition (main effect of condition: $F(1,28) = 10.197$, $p = .003$, $\eta^2 = .267$). The effect of condition was not modulated by the factor "group assignment", $F(1,28) < 1$, but it was affected by electrode position, $F(2,56) = 5.689$, $p = .012$, $\eta^2 = .169$. Post-hoc tests for the electrode positions separately revealed that the effect of condition is restricted to central, $F(1,28) = 15.277$, $p = .001$, $\eta^2 = .353$, and parietal, $F(1,28) = 7.233$, $p = .012$, $\eta^2 = .205$, electrode leads.

**P3b (300–410 ms).** A P3b succeeded the P3a, mainly pronounced at the parietal electrode position (main effect of electrode: $F(2,56) = 40.542$, $p<.001$, $\eta^2 = .591$). Furthermore, it was more pronounced in *Exclusion*, $F(1,28) = 24.991$, $p<.001$, $\eta^2 = .472$. This effect of condition was modulated by electrode position, $F(2,56) = 15.764$, $p<.001$, $\eta^2 = .360$, but not by group assignment ($F(1,28) < 1$). The corresponding post-hoc tests revealed effects of condition at central, $F(1,28) = 18.601$, $p<.001$, $\eta^2 = .399$, and parietal, $F(1,28) = 46.259$, $p<.001$, $\eta^2 = .623$, electrode positions. Group assignment did not modulate the effects.

## Discussion

### Summary of results

The presence of co-players had a significant effect on the credibility of the cover story: According to the questionnaire, subjects assigned to the group *Presence* were more convinced that they were playing with human beings. This effect held for both conditions, *Inclusion* and *Exclusion*. Nevertheless, the higher credibility did not affect NTQ ratings: In both groups, the decrease in the need threat scale scores (belonging, self-esteem, meaningful existence and control) and increase in negative mood when participants were excluded was comparable and no overall group difference was obtained.

ERP data revealed a group difference in the early time range: In the temporal range of the N2 component (130–210 ms), a significant reduction was obtained only in the group *Presence* when participants were excluded. In the P3 range (P3a: 240–300 ms, P3b: 300–410), social exclusion led to a significant increase in amplitudes. This effect, however, was not modulated by the presence of co-players.

### Effect of credibility on the NTQ

Although credibility was increased, perceived ostracism – as measured with the NTQ – was not affected by the physical presence of co-players. This is in line with previous studies showing that participants even felt excluded when they knew that their co-players were computer-generated [14]. The findings also confirmed that there are no differences between social- and cyber-ostracism in the condition *Exclusion* - at least for the needs "belonging" and "meaningful existence" [35]. However, the aforementioned study also found that the communication medium obviously affected other needs, namely "control" and "self-esteem". This differential effect regarding the four fundamental needs can be explained by the experimental setup used. Williams et al. [35] compared computer-mediated communication (i.e. communication in a chat room) with face-to-face discussions, and both variants describe a more-realistic scenario than the virtual ball-tossing game.

Beside the four fundamental needs aforementioned, we did not observe a differential effect on negative mood which would have been in line with previous results comparing interactions with humans or computers [19]. However, a previous Cyberball study [13] indicated a unidirectional relationship between negative mood and need threat as induced by exclusion: an increase in need threat triggers an increase in negative mood, but not *vice versa*. It is therefore unlikely that the presence of co-players selectively affects negative mood, but not need threat in social exclusion.

Further, our data showed no effect of the physical presence of social interaction partners within the Cyberball paradigm. At first sight, this supports the notion that NTQ data are primarily related to the assumed early pre-attentive processes triggered by exclusion in the Cyberball paradigm, and that this mechanism is not modulated by the physical presence of co-players or other manipulations in the game and does not necessarily require intention [12,13,14].

### ERP: Effects in the N2 range

Within the time range of the N2 component (130–210 ms), we obtained an effect of credibility. This effect was limited to *Exclusion* and can therefore not be explained by the physical of (assumed) co-players presence *per se*. The modulation of the amplitude is either related to a decrease in amplitude of the N2 component, or to the superimposition of a unique early ERP positivity.

As stated above, we assumed the N2 to be elicited in the case of ball possession in both conditions, *Inclusion* and *Exclusion*, independently of group assignment [8]. Following our hypothesis, the N2 amplitude reflects the degree of task relevance [30] since ball possession demands a motor reaction from the participant. The differential modulation within this temporal range, however, indicated an early effect of the presence of co-players on social exclusion. Three possible accounts will be discussed in turn.

**Modulation of a conflict-based neural alarm system.** In a recent ERP study using the Cyberball paradigm, an enhancement of N2 amplitude was assumed to signal the activation of a neural alarm system when excluded [9]. Its activation is triggered by a pre-conscious conflict-monitoring system [36]. Following this idea, the decrease of the N2 amplitude observed in our data would signal a down-regulation of the alarm system in the group *Presence*. However, Figure 2 indicates that the N2 was already expressed in *Inclusion*, and was therefore not specifically related to partial exclusion in the ball tossing game [8]. Moreover, the latency of the N2 effect observed (200–320 ms, [9]) rather refers to the P3a time range analyzed in our study. We will therefore consider the activation of this system in the following section.

**Modulation of a defense sensitivity system.** Within an emotional oddball design, a reduction of N2 amplitude was triggered by pleasant stimuli, and assumed to reflect a reduction in the defense system sensitivity [37]. A corresponding process might be elicited in our group *Presence*: Here, the reception of the ball in the exclusion condition signaled a re-involvement in the game and thereby reduces social threat. According to previous results, however, we have to take into account that a N2 reduction in the group *Presence* is expected to be associated with a corresponding modulation of the P3 amplitudes [37]. As stated in the result section, this was not the case in our study.

**Modulation of the social reward signal.** The visual inspection of the grand-averaged ERPs also indicates a transient positivity at frontal and central leads in the group *Presence* within the N2 time range (see Figure 2.B). Therefore, we also have to consider the superimposition of a P2-like process in the exclusion condition. A corresponding ERP process has been reported in reward processing [38,39]: Here, a fronto-central positivity was elicited after receiving unexpected rewards, and neutralized the N200 component. In our study, receiving the ball was comparable to a social reward, and it was probably more valuable in the (partial) exclusion condition. Following this idea, ball possession was treated as a social reward only if the credibility of an interaction with human beings was given. This hypothesis is substantiated by a neuroimaging study indicating that face-to-face interactions activate the reward system to a greater extent than recorded social interactions [40].

In sum, the ERP effect in the N2 time range indicates that the presence of co-players affects an early processing stage involved in the appraisal of social exclusion. We assume that the occasional involvement in the game within an *Exclusion* rally serves as a social reward signal if co-players are present. It is important to note, however, that this process is not directly reflected by the N2, but rather by an independent ERP positivity (P2) superimposed. The more direct account – N2 amplitude as an indicator for social threat – appears to be less convincing since the P3 amplitude is not modulated as well [37,41].

### ERP: Effects in the P3 range

ERP data confirmed results that the P3a and P3b components are sensitive to ostracism manipulation in the Cyberball paradigm [8]. The P3a and P3b effect was also in line with the participants' estimation of ball possession (see Table 1): Both experimental groups provided a valid estimation when comparing the change from inclusion to exclusion, and in both groups a comparable increase of P3 components was observed. Since the effects in the N2 time range (see above) have been related to a differential reward processing between the groups *Internet* and *Presence*, a corresponding effect might be also expected for the P3 amplitudes [42,43]. However, P3 amplitudes were obviously less sensitive to the magnitude of a "social" reward provided by co-players physically present.

As for the P3a, our previous study [8] provided evidence that it was related to the activation of an early alarm system – already implemented in the seminal model on social exclusion [2]. This system was supposed to determine the affective response to exclusion and to be located in the anterior cingulate cortex [5,44]. A previous ERP study also postulated the activation of a conflict-based alarm system in a corresponding temporal window (200–300 ms, [9]), but it was related to a conflict N2 [36]. Within this theoretical framework, one might conclude that the alarm system is activated independently of the credibility of the experimental setup. Accordingly, we did not observe an effect on the negative mood of our participants.

As for the P3b, we previously related its amplitude to the subjective expectancy of social exclusion, i.e. occasional ball reception within an exclusionary rally does not meet the participants' expectation of continuous exclusion [8]. As suggested for the parietal, oddball-triggered P3 complex [26,44], the component is related to controlled processing, such as memory- or context-updating operations and the expectancy towards feedback [45]. The impact of subjective expectancies on ostracism intensity has already been highlighted in studies on rejection sensitivity in healthy and clinical samples [46,47].

We propose that the P3 amplitudes and the NTQ data – replicating earlier results [8] – rely on a common stage in the cognitive processing of social exclusion, namely the expectancy of receiving the ball in the exclusion condition. Both, retrospective behavioral measures and P3 effects were primarily determined by the subjective probability to get involved in the ball tossing game. The credibility of the Cyberball game – significantly increased by the presence of co-players – does obviously not affect the psychological processes subserving the participants' expectancies on involvement.

## Conclusion

The results indicate that psychophysiological (ERP) data reflect different experiences of social exclusion related to facets not covered by the items of the applied self-report measure (NTQ). One facet might be the enhancement of the perception of social rewards when playing with human beings. ERP data are therefore more capable to detect transient processes within the Cyberball game. To cover differential aspects in the processing of social exclusion, the recording of an online measurement is beneficial. When applying the Cyberball game, imaging or electrophysiological techniques as well as analyses of facial expression [5,7,9,48] will provide further insight into the dynamics of processing which may remain hidden in a mere retrospective design.

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## Author Contributions

Conceived and designed the experiments: SW MN. Performed the experiments: SW. Analyzed the data: SW MN. Wrote the paper: SW MN.

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## 6.2 Are there benefits of social overinclusion? Behavioral and ERP effects in the Cyberball paradigm

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# Are there benefits of social overinclusion? Behavioral and ERP effects in the Cyberball paradigm

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Social participation can be examined using the Cyberball paradigm, a virtual ball-tossing game. Reducing the involvement of the participant is supposed to activate a neural alarm system, and to threaten fundamental social needs. Our previous findings indicate that the latter process can be linked to an enhancement of the centro-parietal P3 amplitude, signaling a modulation of the subjective expectancy of involvement. A preceding more frontal ERP component, the P2, does not depend of the probability of involvement, but reflects the appraisal of social reward. In this experiment, we examined whether overinclusion of participants enhances the satisfaction of social needs, reduces the P3 amplitude correspondingly, and affects central reward processing. In the control condition, participants ($n$ = 40) were included (two co-player, ball possession 33%), and overincluded (ball possession 46%) in the experimental condition. In a counterbalanced design, we also controlled for the order of conditions. As predicted, overinclusion increased the satisfaction of social needs, with exception of "self esteem", and reduced the P3 amplitude. As for the frontal P2, overinclusion only enhanced the amplitudes if the less frequent involvement (condition: inclusion) was experienced previously. The behavioral and P3 data suggest that the feelings of social belonging, meaningful existence, and control are related to the subjective expectancy of social involvement, and can be described in terms of a linear continuum ranging from exclusion to overinclusion. In contrast, appraisal of social rewards does not depend on the probability of involvement.

**Keywords: ostracism, Cyberball, ERP, overinclusion, expectation, social reward**

## INTRODUCTION

Social participation appears to be essential for human beings, and is vital to mental and physical health (Cacioppo and Cacioppo, 2012). Research in the last decade was largely based on ostracism, the exclusion of an individual by others (Williams, 2007). Following the seminal model of Williams, social exclusion has an immediate impact on basic human needs, such as the feeling of social belonging, or self-esteem (Williams and Zadro, 2005). Consequently, negative mood and distress is evoked in ostracized subjects.

According to the need-threat model, this first reaction to social exclusion is reflexive and unavoidable. In contrast to perceived fairness in trading games (Moretti and Di Pellegrino, 2010), the emotional response to social exclusion does apparently not rely on the credibility of the experimental setting, and is even triggered if exclusion is overtly scripted (Zadro et al., 2004). Because of its sensitivity and reliability, it has been assumed that the elicitation of the social need threat relies on a precognitive warning system.

In most behavioral and neuroimaging studies, the Cyberball paradigm has been used to elicit social exclusion (Williams et al., 2000; Williams and Jarvis, 2006). In this computerized version of a "ball-tossing" game, the participant is represented as an avatar on a computer screen. Two other avatars putatively represent two other human co-players connected via internet. In the following catch play, a ball is thrown and caught by the avatars. If the participant receives the ball in about a third of a time, "inclusion" is provided. "Exclusion" implies that the two assumed co-players are throwing the ball back and forth. In order to measure the effect of exclusion, the NTQ (Need Threat Questionnaire; Williams et al., 2000) is usually applied subsequent to the Cyberball game. In contrast to inclusion, social exclusion reduces the satisfactory level of belonging (e.g., "I felt disconnected"), self-esteem (e.g., "I felt good about myself"), meaningful existence (e.g., "I felt invisible"), and control (e.g., "I felt powerful"). The increase in need threat is associated with an increase in negative mood (van Beest and Williams, 2006).

Despite the reliability of the Cyberball paradigm in behavioral studies, the neurocognitive signature of social exclusion has not been consistently replicated. Whereas the dorsal anterior cingulate cortex (dACC) was closely related to the perceived distress (Eisenberger and Lieberman, 2004), additional regions of functional relevance were identified in a recent meta-analysis of the imaging data available (Cacioppo et al., 2013). However, these structures (left ACC, anterior insula) are rather related to emotional craving

(Fisher et al., 2010), or uncertainty of decision making (Grinband et al., 2006; Singer et al., 2009) than to physical pain.

A further question is related to the functional specification of the reflexive system activated by ostracism. Following the ostracism model (Williams, 2007), a neural alarm system detects the slightest hint of ostracism, and triggers the reflexive painful response—unmitigated by situational factors. This implies that the reflexive process is unidirectional, and is activated by exclusion only. This idea is apparently substantiated by a Cyberball study (van Beest and Williams, 2006): Here, overinclusion—when contrasted to inclusion—did neither modulate the fundamental needs (as measured by the NTQ) nor negative mood significantly. This pattern of results was replicated in a recent neuroimaging study, and supports the notion of an alarm system selectively triggered by exclusion (Kawamoto et al., 2012). However, the results contrast earlier findings indicating that the inclusionary status follows a linear function, extending from overinclusion to inclusion, partial, and total ostracism (Williams et al., 2000). The expression of the inclusionary status is not only defined by the degree of involvement, but also by the incentives attached to the social involvement (van Beest and Williams, 2006). Both findings support the notion that the central processing of social participation cannot be sufficiently explained in terms of a reflexive process.

As suggested by our previous ERP studies (Gutz et al., 2011; Weschke and Niedeggen, 2013), subjective expectancy is a crucial factor in the evaluation of social participation. We analyzed the ERP responses time-locked to the reception of the ball in the Cyberball game. An experimental block of inclusion (two co-players, 33% ball possession) was compared with partial exclusion (two co-players, 16% ball possession). The target event (ball possession) triggered an ERP response defined by two components: a transient negativity at about 200 ms (N2), and a longer-lasting positivity starting at about 250 ms (P3). The centro-parietal part of the P3 shares the characteristics of the P3 evoked in the Oddball paradigm (Donchin, 1981; Rosenfeld et al., 2005), and signals the subjective probability of a task-relevant event (here: ball reception). Accordingly, the P3 amplitude was significantly enhanced if the ball was received less frequently by the participant. In order to refer to the effect of target probability on P3 amplitude, we will use the term *P3 effect* in the following.

The P3 effect appears to be related to the threat of social needs as measured by the NTQ: The amplitude of the parietal P3 was found to be correlated with the perceived ostracism intensity (Gutz et al., 2011). In contrast, crucial changes in the experimental setup not affecting the NTQ score (i.e., physical presence of co-players, Weschke and Niedeggen, 2013) did also not affect the P3 complex. We therefore concluded that cognitive processes related to the P3 effect, such as context-updating or expectancy towards feedback (Donchin and Coles, 1988, 1991; Hajcak et al., 2005; Polich, 2007), also affect the retrospective questionnaire on social exclusion, the NTQ.

Moreover, we also showed that ERPs can reveal additional cognitive processes related to the evaluation of social exclusion—not measured by means of the NTQ. As mentioned above, physical presence of the excluding co-players neither affected the NTQ nor the P3 effect (Weschke and Niedeggen, 2013). However, physical presence—as compared to the simulation of interaction via internet—enhanced an additional early frontal positivity (P2). This component has been elicited in numerous experimental studies in visual search (Luck and Hillyard, 1994), and memory recognition tasks (Evans and Federmeier, 2007), and was related to feature detection and cognitive matching processes. Moreover, the P2 has also been evoked in studies requiring reward prediction (Potts et al., 2006; Holroyd et al., 2011), and appears to signal the processing and appraisal of unexpected reward signals. Following this idea, ball reception in the Cyberball design might serve as a social reward, and changes in the amplitude of the P2 will therefore signal a modulation of the reward value (Weschke and Niedeggen, 2013).

In the present study, we used the Cyberball-ERP setup to examine the processing of overinclusion in the ball-tossing game. If the need threat system is activated exclusively in case of exclusion (Williams, 2007), overinclusion compared to inclusion should not affect the four fundamental needs (belonging, self-esteem, meaningful existence, and control; see for example Williams and Zadro, 2005). On the other hand, if overinclusion leads to an enhancement of social need satisfaction, the idea of a continuum defining the inclusionary state is supported (Williams et al., 2000). Since the Cyberball design shares the functional properties of the oddball paradigm, overinclusion should also affect the P3 effect. The inverse relationship between P3 amplitude and target probability was already demonstrated in previous oddball studies (Duncan-Johnson and Donchin, 1977; Polich and Margala, 1997). Our analysis did also focus on the P2 range providing insight on the evaluation of the reward (here: ball reception). A modulation of the P2 amplitude will indicate whether the social reward (ball reception) is enhanced or devaluated in case of overinclusion.

The evaluation of social inclusion is probably not only determined by the actual involvement in the game, but also by the previous experience. Transfer effects have recently been reported in two Cyberball experiments (Gutz et al., 2011; Tang and Richardson, 2013): In one study, negative mood was expressed more if social exclusion followed the previous experience of inclusion (Gutz et al., 2011), whereas an ameliorative benefit of inclusion following exclusion was reported in a second one (Tang and Richardson, 2013). We assume that these kinds of "transfer effects" reflect that experienced social participation modulates the expectations for future involvement. If these expectations are not fulfilled, a (re-)construction of a subjective probability model is necessary. Since an asymmetry of the adjustment process was found in our previous work (Gutz et al., 2011), we analyzed whether the behavioral (NTQ) and electrophysiological (P2, P3) effects are differently expressed if overinclusion preceded or followed inclusion.

## MATERIALS AND METHODS

### PARTICIPANTS

The procedure was approved by the local ethics committee at the FU Berlin. Fifty healthy subjects participated in the experiment. Due to a high number of artifacts in the EEG, eight participants had to be excluded. Additionally, two subjects had to be excluded because of missing data in the questionnaire, leaving a total of 40 for analyses. The participants had self-reportedly no history of psychiatric or neurological disorders and were not taking medication affecting the central nervous system. They were recruited in the university environment and gave their written consent for participating according to the Declaration of Helsinki. The subjects were randomly assigned to one of the experimental groups (*Inclusion first* $n$ = 20, 11 female, mean age = 25.4 years; *Overinclusion first* $n$ = 20, 12 female, mean age = 24.1 years). Since a cover story was required to induce the experimental effect, participants were informed about the experimental technique and aiming of the study afterwards. Participants got credit points for their studies.

## TASK AND DESIGN

The experimental setup (Cyberball game including the instructions) was programmed in MATLAB (R2012a, The MathWorks, Inc.). The program also provided the triggers for EEG recording. All participants were told that they took part in a study testing visual imagination capabilities. To keep up this cover story, the subjects first completed a short questionnaire about visual imagination ability (Vividness of Visual Imagery Questionnaire; Marks, 1973).

The setup of the Cyberball design followed an established design (see Gutz et al., 2011): Participants were told that they would play a ball-tossing game with two other co-players connected via internet (see **Figure 1**). For this reason, an internet display was simulated on the computer screen (7° × 7° at a viewing distance of 100 cm) displayed to the participants, including the photos of two putatively connected co-players. The participant could select the player to whom she/he wanted to throw the ball by pressing a corresponding button. To adapt to the technical requirements of ERP recording, animated avatars and a ball trajectory—included in the original Cyberball setup—were avoided: the ball was presented at a centered screen position for 500 ms, and then appeared next to the picture of a player. If one of the ostensible co-players received the ball, the temporal interval for the volley was randomly varied from 400–1.400 ms to enhance the belief of playing with humans.

Following the instructions and a short training introduction, all participants went through two blocks of the Cyberball game. Each block consisted of 200 ball throws and lasted about 7 min. In the experimental condition *Inclusion* (*INC*, proportionate ball possession), the participant received the ball in about one third of all ball throws (33%, approximately 66 times); in the experimental condition *Overinclusion* (*OI*; disproportionate ball possession), the probability of getting the ball was increased to 46% (approximately 92 times).

To account for the contrast effect assumed, the design comprised the between-subject "order of conditions": 50% of the subjects started with the condition *Inclusion* (*INC first*) and the remaining 50% started with the condition *Overinclusion (OI first)*. The within-factors were defined by the probability of ball reception ("probability": *INC* vs. *OI*), and the electrode positions

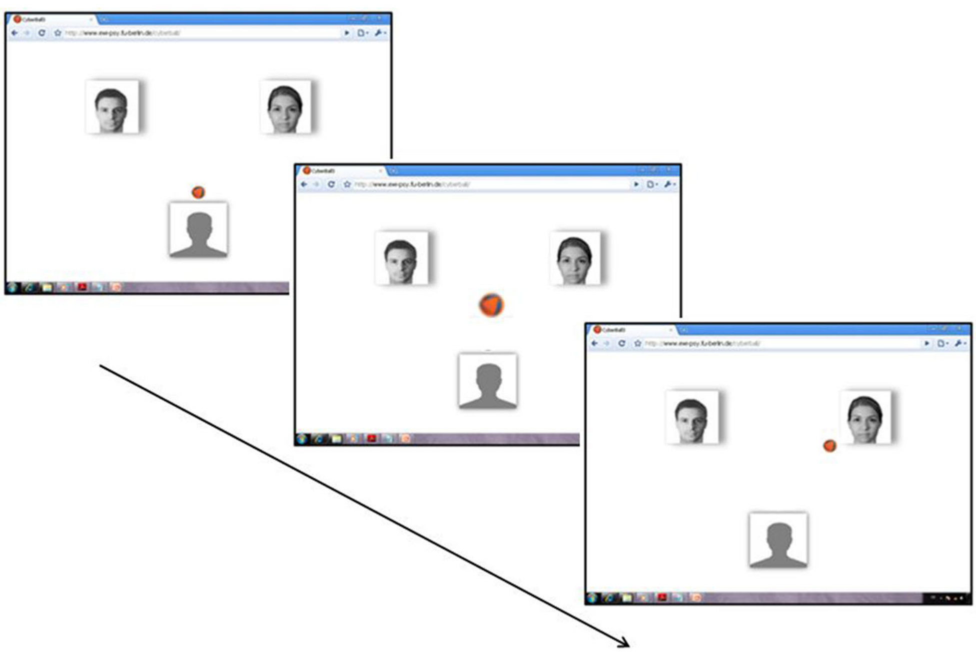

**FIGURE 1 | Cyberball-ERP design: An internet display was imitated on the computer screen including the photos of two ostensible connected co-players**. The participant passed the ball to a co-player by pressing a corresponding button. Then, the ball appeared on a central position for 500 ms, and finally appeared next to the photo of the co-player. Ball possession of a co-player followed a computer-generated random time interval varying from 400–1.400 ms. The photographs of co-players depicted—and used in the experiment for all participants—refer to morphs of portraits taken from different persons. (For the setup of the screen: see Weschke and Niedeggen, 2013).

(see below). As for the analysis of the ERPs, the analysis was focused on the ball reception of the participants.

After the second block, two NTQ questionnaires were handed out. The subjects were told to retrospectively fill out the questionnaires, the first one regarding the first block, and the second one regarding the second block. To make the separation of the two experimental blocks less difficult, one part of the ball-tossing game had to be imagined in the meadow and the other game on a beach. As already indicated in our previous studies (Gutz et al., 2011; Weschke and Niedeggen, 2013), the NTQ can reliably differentiate between the *Inclusion* and *Exclusion* condition, even if ratings on the first block are to be delivered with a temporal delay.

Beside of the NTQ, subjects had to estimate the probability of receiving the ball in the corresponding blocks. Moreover, the NTQ includes two scales measuring "negative mood" (e.g., "I felt angry") and "perceived ostracism intensity" (e.g., "I was excluded"), which were extracted from the "Aversive Impact Index" (see for example Williams et al., 2000). Participants were also asked to rate the credibility of the cover story on a 5-point Likert scale ("My co-players were computer-generated.").

After completing all questionnaires, the subjects were informed about the real aim of the study, and about the scripted behavior of the putative co-players.

### EEG RECORDING AND DATA ANALYSIS

#### *EEG data*

EEG data were recorded from 9 active electrode positions (frontal: F3, Fz, F4, central: C3, Cz, C4; parietal: P3, Pz, P4). Previous experiments had shown that these positions are highly sensitive to record the components of interest (Gutz et al., 2011; Weschke and Niedeggen, 2013). Ag/AgCl electrodes were embedded in an electrode cap (EASYCAP, Herrsching, Germany) mounted on the subjects' head, and filled with electrode cream (Abralyt 2000, EASYCAP). Active electrodes (impedance $< 5$ kΩ) were referenced to linked earlobes ($< 5$ kΩ), with FCz serving as ground. Vertical and horizontal electrooculogram (EOG) were also recorded to control for ocular artifacts ($< 20$ kΩ). Biosignals were recorded continuously with a 40-channnel NuAmps amplifier (Software Acquire, Neuroscan Labs, Neurosoft, Inc., El Paso, TX). Data were band-pass filtered on-line (0.1–200 Hz) and sampled at 500 Hz. Off-line, EEG data were analyzed using "Brain Vision Analyzer" (Version 1.05, Brain Products GmbH, Gilching, Germany). EEG was segmented according to the onset of ball possession (−100–700 ms epoch length), filtered (0.3–30 Hz), and baseline corrected (−100–0 ms). Single EEG sweeps containing muscular or ocular artifacts were excluded from analysis, as well as EEG trials with high Alpha activity. Since there were more segments for ball possession in the condition *Overinclusion* by definition, the number of EEG segments was randomly chosen to adjust it to the number of segments obtained in the condition *Inclusion*. Averages and grand averages were calculated, separately for the two experimental groups (order of conditions), experimental conditions (probability), and nine active electrodes. Grand averages revealed three distinctive components: N2 (120–170 ms), an partially overlapping P2 (150–210 ms), and a sustained P3 complex with a parietal maximum extending from 320–400 ms. Mean amplitudes in these time windows were exported and analyzed using SPSS (version 19, IBM). Repeated measures ANOVAs were calculated including the between-subject factor "order of conditions" (*INC first* vs. *OI first*) and the within-subject factors "probability" (*INC* vs. *OI*), "electrode caudality" (frontal vs. central vs. parietal) and "electrode laterality" (left vs. central vs. right). Degrees of freedom and $p$-values were corrected according to Greenhouse-Geisser, if indicated, and corrected $p$-values will be reported in the following.

#### *Behavioral data*

For each participant, data of the NTQ and additional questions were read in SPSS (version 19, IBM) and NTQ scales were computed. The data were analyzed running a repeated measures ANOVA including the between-subject factor "order of conditions" (*INC first* vs. *OI first*) and the within-subject factor "probability" (*Inclusion* vs. *Overinclusion*). The four NTQ scales (belonging, self-esteem, control, meaningful existence) with a possible range of 1–5 were analyzed running a MANOVA. The data obtained for negative mood (e.g., "I felt sad") (possible range: 4–20) and the perceived ostracism intensity (e.g., "I felt ostracized") (possible range: 2–10) were analyzed in a separate ANOVA.

## RESULTS

### BEHAVIORAL DATA

Behavioral data are presented in **Table 1**. The experimental manipulation of inclusion and overinclusion was reliably perceived by the participants: although the frequency of ball possession was slightly underestimated in both conditions (*INC*: 28.5%; *OI*: 44.9%), the difference between the mean estimated frequencies was significantly expressed ("probability": $F_{(1,38)} = 54.66$, $p < 0.001$, $\eta^2 = 0.59$). This main effect was not modulated by the between-factor "order of conditions" ($F_{(1,38)} = 0.954$, n.s.).

The questionnaire also revealed that participants believed that the co-players were computer-generated (*INC*: $M = 4.05$, $SD = 1.26$; OI: $M = 3.95$, $SD = 1.38$). The credibility rating was comparable to the rating obtained in our previous study (Weschke and Niedeggen, 2013), and was not modulated by probability and group assignment.

Although a speeded response was not requested, participants' reaction times were significantly decreased in the second block (first block: $M = 660$ ms, $SD = 175, 8$ ms; second block: $M = 595$ ms, $SD = 154, 96$ ms; $F_{(1,38)} = 11.58$, $p = 0.002$, $\eta^2 = 0.23$). The effect on response time was not modulated by group assignment, and did therefore not depend on the probability of ball possession.

The four NTQ scales were also significantly affected by the frequency of ball possession (MANOVA: $F_{(4,35)} = 5.47$, $p = 0.002$, $\eta^2 = 0.39$), although the temporal order of blocks did not elicit a significant interaction ($F_{(4,35)} = 2.01$, $p = 0.190$). In more detail, overinclusion led to a significant increase in the scales "belonging" ($F_{(1,38)} = 14.01$, $p < 0.001$, $\eta^2 = 0.28$), "meaningful existence" ($F_{(1,38)} = 11.49$, $p = 0.002$, $\eta^2 = 0.23$), and "control" ($F_{(1,38)} = 18.18$, $p < 0.001$, $\eta^2 = 0.32$), but not "self-esteem", ($F_{(1,38)} = 0.00$, n.s.). In none of the scales, temporal order of the blocks was found to modulate the effect of overinclusion

**Table 1 | Behavioral results obtained in the two experimental conditions *Inclusion* (INC, ball possession 33%) and *Overinclusion* (OI, ball possession 46%)**.

| | INC | | OI | |
|---|---|---|---|---|
| **GROUP** | **INC first** | **OI first** | **INC first** | **OI first** |
| Estimated percentage of ball possession | 29.90 (8.6) | 27.20 (9.2) | 48.40 (10.0) | 41.4 (11.1) |
| Belonging | 3.78 (0.62) | 3.67 (1.04) | 4.40 (0.47) | 4.10 (0.63) |
| Self-esteem | 3.52 (0.44) | 3.15 (0.62) | 3.33 (0.47) | 3.33 (0.55) |
| Meaningful existence | 4.47 (0.63) | 4.05 (0.97) | 4.72 (0.45) | 4.65 (0.51) |
| Control | 2.27 (0.72) | 2.12 (0.77) | 3.00 (0.70) | 2.62 (0.90) |
| Negative mood | 10.43 (1.70) | 10.60 (1.78) | 9.70 (1.71) | 9.85 (1.56) |
| Perceived ostracism | 4.20 (2.01) | 4.75 (2.38) | 2.45 (1.39) | 2.45 (1.10) |

*Mean values and standard deviations (in brackets) are provided for the two experimental groups (INC first: INC followed by OI; OI first: OI followed by INC).*

(interaction with probability: "belonging" ($F_{(1,38)} = 0.46$, $p = 0.50$, $\eta^2 = 0.012$), "meaningful existence" ($F_{(1,38)} = 1.95$, $p = 0.17$, $\eta^2 = 0.05$), "control" ($F_{(1,38)} = 0.65$, $p = 0.43$, $\eta^2 = 0.02$), "self-esteem", ($F_{(1,38)} = 3.30$, $p = 0.08$, $\eta^2 = 0.08$).

Two additional scales were reflecting the affective and cognitive evaluation of the social participation in the Cyberball game: negative mood was significantly decreased in overinclusion as compared to inclusion ($F_{(1,38)} = 30.26$, $p < 0.001$, $\eta^2 = 0.44$), as well as the perceived ostracism intensity ($F_{(1,38)} = 8.11$, $p = 0.007$, $\eta^2 = 0.18$). Again, temporal order did not modulate the effects significantly.

In none of the scales, a significant main effect of the between-factor "order of conditions" was found.

### ERP DATA

The grand-averaged ERPs evoked by the event "ball possession" are depicted in **Figure 2**. Three time ranges were exported for further analyses: The N2 range (130–180 ms) was marked by a parietal negative peak at about 170 ms, and released by a marked frontal positivity mostly expressed in the condition "over-inclusion" (P2, 150–210 ms). Replicating our previous findings (Gutz et al., 2011; Weschke and Niedeggen, 2013), ball reception triggered a late positive complex with a centro-parietal maximum extending from 320–400 ms (P3). The following analysis was focused on the P2 and P3. In line with our previous results, no effect on the N2 amplitude was induced by modulating the probability of ball reception.

#### *P2 (150–210 ms)*

According to the grand-averaged ERPs (see **Figure 2A**), the P2 amplitude appears to be more expressed in the condition "over-inclusion". The ANOVA confirmed a significant main effect of "probability" ($F_{(1,38)} = 7.000$, $p = 0.012$, $\eta^2 = 0.156$). The effect of probability, however, was significantly modulated by the factor "caudality" and the order of experimental conditions ("probability" × "caudality" × "order of conditions": $F_{(2,76)} = 12.346$, $p < 0.001$, $\eta^2 = 0.245$). The interaction of the relevant two experimental factors (probability, order) was only confirmed at frontal leads ("order of conditions" × "probability": $F_{(1,38)} = 4.797$, $p = 0.035$, $\eta^2 = 0.112$), but not at central and parietal leads (each $p > 0.1$). As revealed in **Figures 2A,B**, the difference between the inclusionary states was only found to be significant for the experimental group of subjects starting with inclusion (*INC first*, "probability": $F_{(1,19)} = 21.065$, $p < 0.001$, $\eta^2 = 0.526$), but not for the group starting with overinclusion (*OI first*, "probability": $F_{(1,19)} = 1.724$, $p = 0.205$). None of the effects aforementioned was modulated by the laterality of the electrodes.

#### *P3 (320–400 ms)*

The positive amplitude was more expressed in the inclusion condition as compared to overinclusion (**Figure 2A**). The effect of probability was differently expressed at frontal, central, and parietal electrode positions ("caudality" × "probability": $F_{(2,37)} = 11.857$, $p < 0.001$, $\eta^2 = 0.391$). Separate analyses for the three clusters showed that P3 effects were significantly expressed at central and parietal leads, with larger effects at the parietal ("probability": $F_{(1,38)} = 22.252$, $p < 0.001$, $\eta^2 = 0.369$) as compared to the central leads ("probability": $F_{(1,38)} = 15.252$, $p < 0.001$, $\eta^2 = 0.286$). Although mean amplitudes appeared to be more expressed in the group *INC first*, the between-subject factor "order of conditions" was not significant ($F_{(1,38)} = 0.926$, n.s.). Moreover, neither laterality nor temporal order did modulate the effect of probability.

## DISCUSSION

### SUMMARY OF RESULTS

Overinclusion had a remarkable effect on the processing of social participation: Following the NTQ data, increasing the probability of ball possession significantly increased the scales "belonging", "meaningful existence", and "control". Furthermore, negative mood was significantly decreased, as well as the perceived ostracism intensity. The behavioral data indicate an enhancement of social need satisfaction. These effects were associated with a corresponding decrease in the P3 amplitude. A similar effect can be obtained in the oddball paradigm, if target frequency is increased (Polich and Margala, 1997).

The temporal order of the experimental conditions "inclusion" and "overinclusion" did neither modulate the behavioral nor the P3 effect aforementioned. In contrast to our predictions, an asymmetry in the adjustment of subjective expectancy depending on the temporal order of the conditions was not found. However, the temporal order had a selective effect on the frontal P2, previously related to the appraisal of social reward signals (Weschke and Niedeggen, 2013). This component was significantly increased in

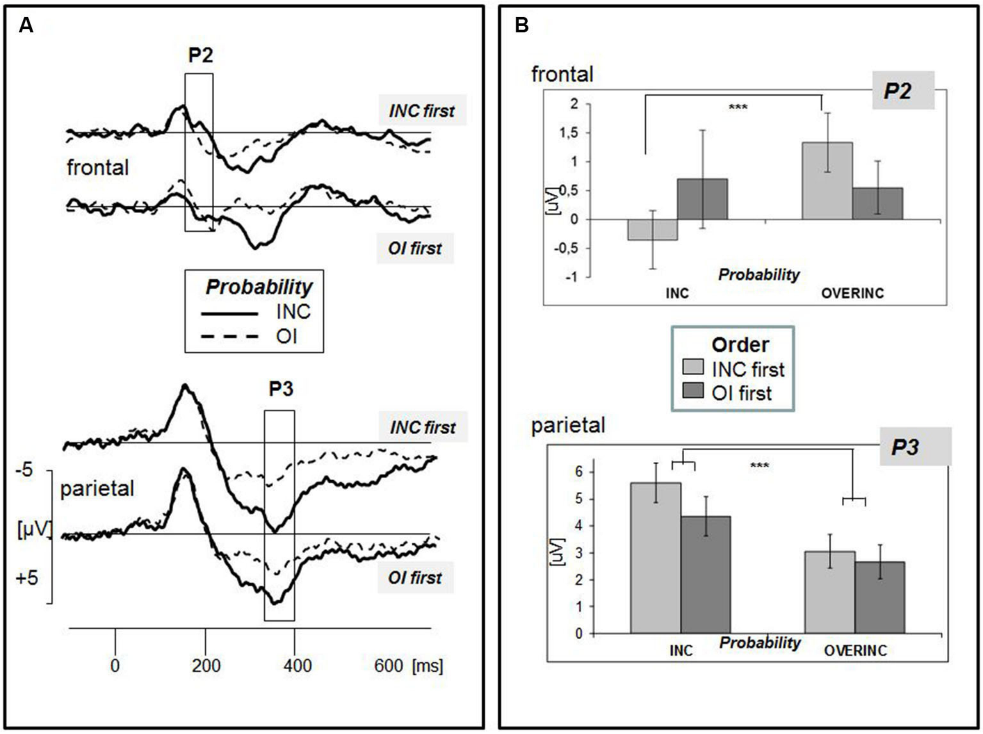


**FIGURE 2 | (A)** Grand-averaged ERPs for the event "ball possession of the participant" separated for the two experimental groups (order of condition: "INC first" vs. "OI first"). Electrodes are pooled to the clusters "frontal" and "parietal". Two experimental conditions related to different probabilities of ball possession are superimposed (INC: inclusion, 33%; OI: overinclusion, 46%). Amplitude differences between the conditions were observed in two time windows, 150–210 ms (P2, see frontal leads) and 320–400 ms (P3, see parietal leads). **(B)** Mean ERP amplitudes of the two components separated for the effect of experimental condition "probability" (inclusion vs. overinclusion) and "order of conditions" (inclusion first vs. overinclusion first). Bars indicate the standard error of mean.

case of overinclusion—given the previous experience of inclusion. A corresponding ERP effect was not obtained if overinclusion preceded inclusion.

These results will be discussed in detail.

## BEHAVIORAL EFFECTS OF OVERINCLUSION

Behavioral data on the effect of overinclusion in Cyberball are not consistent. In a first internet-based study (Williams et al., 2000), the inclusionary status was varied in four degrees (complete exclusion, partial exclusion, inclusion, and overinclusion), and a significant relationship to the NTQ scales "belonging" and "self-esteem" was found. The linear effect also extends to the participants' mood, and apparently supports the idea of an inclusionary continuum. The data obtained in two other studies (van Beest and Williams, 2006; Kawamoto et al., 2012) provided no evidence indicating that overinclusion affects self-reported social pain. They rather revealed that distinct neural networks are involved if participants are excluded, such as the dACC, or the right ventrolateral prefrontal cortex (Kawamoto et al., 2012). The latter is in line with the assumption that the neural alarm system is exclusively activated by ostracism, but not affected by overinclusion.

Our findings add some new aspects to the ongoing discussion: Summarizing the single NTQ scales, a significant effect of overinclusion indicated an enhancement of social need satisfaction. In line with the reduction of negative mood one might conclude that overinclusion is experienced more positive than inclusion. The findings are in contrast to the behavioral results aforementioned (van Beest and Williams, 2006; Kawamoto et al., 2012), and appear to be more compatible with the idea of an inclusionary continuum resembling the characteristics of a "sociometer". The up- and down-regulation of need threat and mood—triggered by ball possession in the Cyberball game—are probably related to an internal gauge monitoring the degree of social acceptance (Leary et al., 1998). The lack of an effect of overinclusion in previous studies can rather be related to differences in the experimental setup: In one study (van Beest and Williams, 2006), the addition of financial incentives apparently affected the subjective well-being of the participants in the Cyberball setup. In another study (Kawamoto et al., 2012) multiple short blocks of inclusion, overinclusion, and exclusion were presented, and the subjects apparently had to fill out questionnaires between these blocks.

However, we have to consider the NTQ scale not modulated by overinclusion—self-esteem. Self-esteem has been closely attached to the perception of rejection in the sociometer model (Leary et al., 2001). This dissociation within the NTQ scales might signal that self-esteem is not an inner gauge of social acceptance, but a generalized indicator of interpersonal appeal (Blackhart et al., 2009). One might also speculate that some components related to a social need-threat model (Williams, 2007) are selectively affected by social rejection, but not by social acceptance. This is in line with neuroimaging studies: Structures in the ACC and prefrontal cortex are exclusively activated by exclusion, but not by overinclusion (Kawamoto et al., 2012).

### ERP CORRELATES OF OVERINCLUSION

As previously observed for the case of social exclusion induced in the Cyberball game (Gutz et al., 2011; Weschke and Niedeggen, 2013), overinclusion affected the P3 effect: The P3 amplitude was significantly reduced if the involvement in the ball-tossing game was increased. The effect corresponds to the participants' estimation of ball possession (see **Table 1**), and was—in contrast to the preceding P2—not modulated by the order of the experimental conditions.

With respect to the frequency of the target event (ball possession), the P3 effect observed in Cyberball shares the characteristics of the oddball-triggered P3 complex related to controlled processing, such as context updating (Donchin, 1981) and the modulation of subjective probabilities (Duncan-Johnson and Donchin, 1977). In case of social exclusion, the significant increase of P3 amplitude was supposed to reflect the re-adjustment of subjective expectancy of social participation (Gutz et al., 2011; Weschke and Niedeggen, 2013). In an exclusionary rally, the enhancement of the P3 effect triggered by casual ball receptions can be related to the processing of unexpected feedback (Hajcak et al., 2005). Increasing the frequency of the task-relevant event correspondingly decreases the amplitude of the P3 amplitude (Polich and Margala, 1997), and this effect applies for the increase in ball possession in overinclusion, too.

We have previously proposed that the expectancy of getting included in the Cyberball game is reflected in the P3 effect, and affects the responses in the retrospective questionnaire, NTQ (Weschke and Niedeggen, 2013). Our recent data indicate that this relation holds for most of the NTQ scales ("belonging", "meaningful existence", and "control"), but not for "self-esteem". We already proposed in a previous study (Weschke and Niedeggen, 2013) that the NTQ scales—related to the feeling of social belonging and control in social interaction—provide a retrospective measure of the status of social acceptance, and are determined by the subjective probability of involvement. For these scales, P3 can serve as an online-measurement of systematic variation. State self-esteem is obviously less dependent on subjective expectancies in social interactions, and is apparently closely related to the direct experience of social rejection.

Although subjective expectancy apparently affects both, NTQ scales and the P3 amplitude, significant correlations of questionnaire and electrophysiological data were not obtained. The lack of predictive power in single participants is probably due to the temporal lag between the experience of social participation and its rating in the questionnaire. Please note that both questionnaires, the one referring to inclusion and the one referring to overinclusion, were to be answered following the second block.

### TRANSFER EFFECTS

In contrast to earlier findings based on the transition from inclusion to exclusion (Buckley et al., 2004; Gutz et al., 2011; Tang and Richardson, 2013), we found no evidence in the questionnaire data for a transfer effect between inclusion and overinclusion in the behavioral data. Previous experience of overinclusion (group: *OI first*) did not enhance the expectation of further social inclusion, and social needs are obviously not threatened by the—relative—decrease in ball possession in the second block. An asymmetry in adjustment processes was also not obtained in our online-measurement, the P3 effect.

The lack of a transfer effect probably indicates that the reconstruction of subjective probabilities of social involvement is a rather fast process. This corresponds to earlier findings obtained in the oddball paradigm (Lindín et al., 2004) providing evidence that adjustment to a low target probability required less than 100 trials.

However, an asymmetry in the order of experimental conditions was obtained for the frontal P2. Its amplitude was significantly increased in case of overinclusion, given that inclusion was experienced previously. If overinclusion preceded inclusion, no such effect was found. A corresponding ERP reflection with comparable latency and topography has been also identified in a previous Cyberball study (Weschke and Niedeggen, 2013), and its amplitude was modulated by the physical presence of the co-players in an exclusion condition as compared to the—putative—internet connection. In line with studies on reward prediction (Potts et al., 2006; Holroyd et al., 2011), the P2 was related to the processing of an unpredicted—here: social—reward signal. The actual study points out that overinclusion in the Cyberball game does not provide a higher social reward *per se*, but depends on the preceding experience of the participant.

The differential effects on P2 and P3 amplitudes also emphasize that multiple affective and cognitive mechanisms contribute to the central processing of social exclusion elicited in the Cyberball paradigm.

## CONCLUSION

In case of overinclusion in the Cyberball game, the modulation of feelings of social belonging and control is in line with the idea of an inclusionary continuum. The retrospective evaluation is related to the participants' expectancy on involvement—as reflected in the P3 effect. Expectancy, however, is not related to the participant's self-esteem which appears to be more sensitive to ostracism. Finally, the ERP data reveal that the evaluation of social reward signals in Cyberball depend on previous experience.

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## 6.3 ERP effects and perceived exclusion in the Cyberball paradigm: correlates of expectancy violation?

Sarah Weschke & Michael Niedeggen

**Title:** ERP effects and perceived exclusion in the Cyberball paradigm: correlates of expectancy violation?

**Running title:** Expectancy violations in the Cyberball paradigm

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**Abstract**

A virtual ball-tossing game called Cyberball has allowed the identification of neural structures involved in the processing of social exclusion by using neurocognitive methods. However, there is still an ongoing debate if structures involved are either pain- or exclusion-specific or part of a broader network. In electrophysiological Cyberball studies we have shown that the P3b component is sensitive to exclusion manipulations, possibly modulated by the probability of ball possession of the participant (event "self") or the presumed co-players (event "other"). Since it is known from oddball studies that the P3b is not only modulated by the objective probability of an event, but also by subjective expectancy, we independently manipulated the probability of the events "self" and "other" and the expectancy for these events. Questionnaire data indicate that social need threat is only induced when the expectancy for involvement in the ball-tossing game is violated. Similarly, the P3b amplitude of both "self" and "other" events was a correlate of expectancy violation. We conclude that both the subjective report of exclusion and the P3b effect induced in the Cyberball paradigm are primarily based on a cognitive process sensitive to expectancy violations, and that the P3b is not related to the activation of an exclusion-specific neural alarm system.

**Keywords:** social exclusion; Cyberball; P3b; probability; expectancy

## 1. Introduction

Belonging to a group is essential for physical and psychological health (Baumeister & Leary, 1995). Therefore perceiving exclusion at an early stage is necessary to take steps to cope with this experience. Williams and colleagues (e.g. Williams & Zadro, 2001) established the need-threat model which states that four fundamental social needs – belonging, self-esteem, meaningful existence, and control – are immediately threatened by social exclusion or ostracism. This is perceived as a socially painful event and serves as an early detection system for social exclusion. It motivates a person to restore the satisfaction of the fundamental needs (Williams, 2007; Williams & Zadro, 2005).

Most studies on ostracism use the Cyberball paradigm (Williams, Cheung & Choi, 2000; Williams & Jarvis, 2006) to investigate social exclusion in a controlled environment: participants are told to play a virtual ball-tossing game with presumed co-players connected via internet which are actually computer-generated. The possibility of receiving the ball is experimentally manipulated. In an inclusion condition there is an even distribution of ball possession between the players, and in an exclusion condition the participant hardly ever receives the ball. To measure the effects of social exclusion, the Need Threat Questionnaire (NTQ, Williams et al., 2000) is given to the participants afterwards to quantify the perceived threat of the fundamental social needs.

Online measurements such as the recording of cerebral blood flow (Eisenberger, Lieberman & Williams, 2003; Somerville, Heatherton & Kelley, 2006) or electrophysiological signals (Gutz, Küpper, Renneberg & Niedeggen, 2011; Kawamoto, Nittono & Ura, 2013; Themanson, Khatcherian, Ball & Rosen, 2013; Weschke & Niedeggen, 2013) during the Cyberball game gave further insight into the cognitive and affective mechanisms determining the processing of social exclusion. The first neuroimaging studies (Eisenberger, 2012; Eisenberger et al., 2003) suggested that the processing of social and physical pain relies on shared neural substrates like the dorsal anterior cingulate cortex (dACC) and the anterior insula. In a more cognitive interpretation, these regions are rather involved in the processing of expectancy violation (Somerville et al., 2006) or represent pain-unspecific structures which are part of a “saliency network” (Iannetti, Salomons, Moayedi, Mouraux & Davis, 2013). A recent meta-analysis emphasized the activation of the anterior insula, the left ACC, and left inferior orbito-frontal cortex while experiencing social exclusion (Cacioppo et al., 2013). Following the authors of the meta-analysis, the joint activation pattern signals social uncertainty, rumination, distress, and craving during exclusion, but not social pain *per se*.

Through its high temporal resolution electroencephalography provides another way to investigate the processing of social exclusion. As demonstrated in our previous studies, the analysis of event-related brain potentials (ERPs) allows us to identify covert processes not detected by retrospective questionnaires (Niedeggen, Sarauli, Cacciola & Weschke, 2014; Weschke & Niedeggen, 2013). In most studies, analyses were focused on the exclusionary events, i.e. ball possession of a co-player (event “other”). Earlier ERP components like N2 and P3 were associated with the activation of the neural alarm system within the Cyberball framework (Crowley, Wu, Molfese & Mayes, 2010; Kawamoto et al., 2013; Themanson et al., 2013). A late (> 400 ms) prefrontal positivity was identified supposed to signal coping mechanisms (Crowley et al., 2009).

Kawamoto et al. (2013), picking up the diverse interpretations of previous fMRI studies, noticed that there is an ongoing debate on which factors, social pain or the probability of ball reception, reflect the processing of ostracism. In ERP literature, the processing of stimulus probability is usually examined by using an oddball paradigm (Duncan-Johnson & Donchin, 1977; Polich & Margala, 1997). Here, the frequency of a task-relevant event is varied systematically. Following this approach, we used a partial exclusion condition in our previous studies allowing a separate analysis of ERP responses to the event “self” (= ball possession of the participant). In line with an early Cyberball study (Williams et al., 2000), partial exclusion was found to be sufficient to trigger need threat and negative feelings (Gutz et al., 2011). Transferring the language of the Cyberball to the oddball paradigm, the event “self” served as target stimulus because it requires a reaction from the participant, whereas the event “other” served as standard or non-target stimulus. In line with the established ERP signatures identified in the oddball paradigm (Katayama & Polich, 1996), the parietal P3 (P300 or P3b) amplitudes were more expressed for target stimuli (event “self”) compared to non-targets (event “other”). For the event “self”, the P3b amplitude was affected by stimulus probability and/or expectancy (Gutz et al., 2011; Weschke & Niedeggen, 2013). Similar results were found in independent ERP-Cyberball studies, but they were not interpreted within the oddball framework and stimulus probabilities (Kawamoto et al., 2013; Themanson et al., 2013). Although some of the earlier findings revealed a correlation between the P3b amplitude and perceived ostracism intensity or social pain (Gutz et al., 2011; Kawamoto et al., 2013), it is questionable whether the P3b is a direct correlate of social exclusion, and part of the neural alarm system. We suggest that it is more likely that the enhancement of P3b amplitudes in the Cyberball paradigm is based on the subjective expectancy for ball possession. Following this idea, the process is reversed in the event “other” (ball possession of a co-player): as indicated by previous oddball experiments (Katayama & Polich, 1996), an increase of the non-target event (“other”) will diminish the P3b amplitude.

In our modified Cyberball task, we independently varied two experimental factors which are commonly intermingled in experimental research on subjective expectancy, and social exclusion: (a) probability of ball possession, and (b) expectancy for ball possession. The first factor was defined by the objective probability of ball possession, and the second factor was varied by changing the number of co-players from the first to the second block of the game. In case that the probability of ball possession was reduced, and the number of co-players was held constant, expectancy of the participant to get involved was violated (group “exclusion”). In case that the probability of ball possession was reduced, and the number of co-players was increased, expectancy of the participant to get involved was not necessarily violated (group “expectancy-control”, see Figure 3).

ERP analyses were focused on the parietal P3b component. Since the P3b amplitude is not only affected by objective probability, but also a correlate of subjective probability or expectancy (Donchin, 1981; Duncan-Johnson & Donchin, 1977), it was hypothesized that the reduction of probability of ball possession (event “self”) would increase the P3b amplitude only in the condition “exclusion”. In contrast, we expected no corresponding modulation of the P3b amplitude in the condition “expectancy-control” because subjective expectancy was assumed to adapt to the number of events (= increase of co-players).

Extending our previous studies (Gutz et al., 2011; Niedeggen et al., 2014; Weschke & Niedeggen, 2013), we also analyzed the event “other” (ball possession of co-players). Here, we expected mirror-image effects: as a correlate of probability, the P3b amplitudes should be more pronounced during inclusion as compared to exclusion at least in the “exclusion” group (Katayama & Polich, 1996; Kawamoto et al., 2013). However, the event “other” shares some similarities with a nogo trial in a go/nogo task, leading to the involvement of additional processes like inhibition, which are expressed in a frontocentral P3 (Bruin & Wijers, 2002). Therefore, also the analyses of the event “other” were restricted to the parietal P3b which is more sensitive to subjective probability and expectancy. This also allowed us to directly compare the effect of expectancy on the P3b elicited by both “self” and “other” events.

In addition to the ERP data, we also analyzed the subjective report of exclusion by means of the Need Threat Questionnaire (NTQ, Williams et al., 2000; Williams & Zadro, 2001). We hypothesized that perceived exclusion would reflect the behavior of the P3b amplitude of the event “self”: a reduction of fundamental social needs was expected only in the condition “exclusion”, violating the social expectations of the subjects.

## 2. Results

### 2.1 Questionnaire data

Probability of ball possession in the first block (ball possession 33%) were underestimated in both groups (“expectancy-control”: *M* = 28.27%, *SD* = 6.40%; “exclusion”: *M* = 27.20%, *SD* = 9.59%), but more accurately estimated in the second block (ball possession 17%) (“expectancy-control”: *M* = 14.40%, *SD* = 5.12%; “exclusion”: *M* = 16.40%, *SD* = 8.06%). The difference between blocks was significant, $F(1,28) = 62.82$, $p < .001$, $\eta_p^2 = .69$, and this effect was not modulated by group, $F(1,28) < 1$.

Descriptive NTQ data (see Table 1) suggest a reduction of need satisfaction after the second block in the exclusion group (here: number of co-players remained constant), but not in the expectancy-control group (here: number of co-players were increased).

**Table 1.** Means and standards deviations (in brackets) of the four NTQ scales for the two experimental conditions “block 1” (33% ball possession), and “block 2” (17% ball possession), and two experimental groups. In the exclusion group, there were two co-players in the second block; in the expectancy-control group, there were five co-players.

| | Group “exclusion” | | Group “expectancy-control” | |
|---|---|---|---|---|
| **NTQ scale** | **Block 1** | **Block 2** | **Block 1** | **Block 2** |
| Belonging | 3.84<br>(0.82) | 2.71 *<br>(1.25) | 3.76<br>(0.79) | 4.02<br>(0.60) |
| Self-esteem | 3.58<br>(0.53) | 2.96<br>(1.06) | 3.49<br>(0.74) | 3.29<br>(0.78) |
| Meaningful existence | 4.31<br>(0.93) | 3.44 *<br>(1.21) | 4.58<br>(0.43) | 4.58<br>(0.70) |
| Control | 1.89<br>(0.88) | 1.47 *<br>(0.71) | 1.96<br>(0.69) | 1.84<br>(0.70) |

*Note*. * $p < .05$ between block 1 and block 2 within groups.

Repeated measures ANOVA including the factors “group” and “block” revealed a significant interaction of these factors for belonging, $F(1,28) = 9.91$, $p = .004$, $\eta_p^2 = .26$, and meaningful existence, $F(1,28) = 4.77$, $p = .04$, $\eta_p^2 = .15$, which was caused by a significant decrease of belonging, $F(1,14) = 8.68$, $p = .01$, $\eta_p^2 = .38$, and meaningful existence, $F(1,14) = 5.27$, $p = .04$, $\eta_p^2 = .27$, in the exclusion group, but not in the expectancy-control group ($p$s $\geq .25$). Due to the small sample size, the interactions for self-esteem ($F(1,28) = 1.41$, $p = .25$) and control ($F(1,28) = 1.43$, $p = .24$) did not reach significance, although there was a significant reduction of control, $F(1,14) = 5.92$, $p = .03$, $\eta_p^2 = .30$, and a nearly significant reduction for self-esteem, $F(1,14) = 4.26$, $p = .06$, $\eta_p^2 = .23$, in the exclusion group, which was not obtained in the expectancy-control group ($p$s $\geq .31$).

## 2.2 ERP data

**2.2.1 P3b amplitudes.** The events “ball possession of the participant” (event “self”) and “ball possession of a co-player” (event “other”) evoked a P3 complex with a posterior P3b which was mostly pronounced at Pz (see Figure 1 for midline ERPs for the “exclusion” group). In the second experimental block, the P3b elicited by the event “self” was enhanced. In contrast, the P3b elicited by the event “other” was reduced.

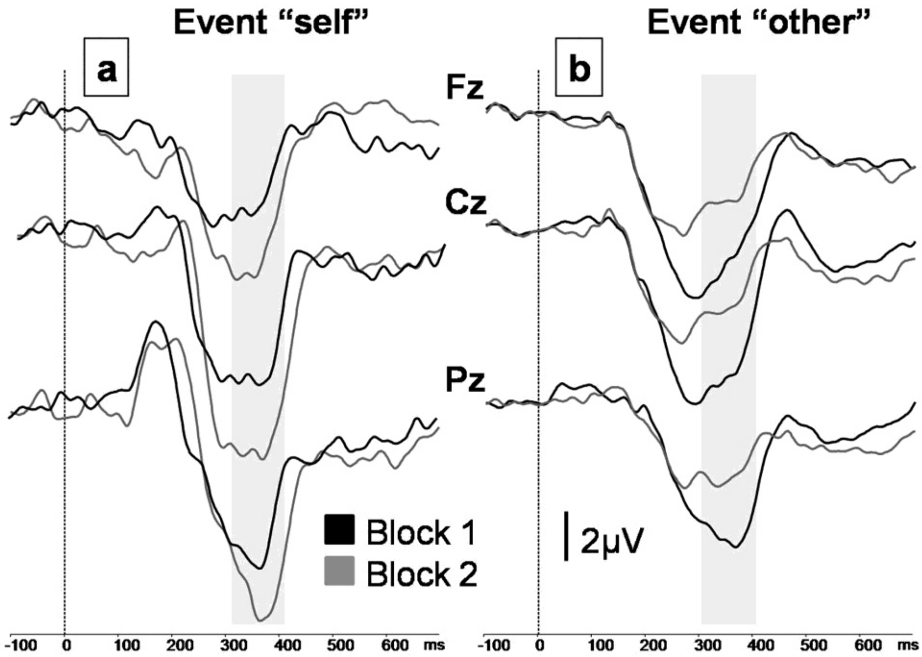


**Figure 1.** Midline ERPs of the "exclusion" group for the events "ball possession" (a) and "ball possession of a co-player" (b), which were presented at 0 ms. Positive voltage is plotted downwards. The probability of the event "self" (a) was 33% in block 1 and 17% in block 2. A negativity at about 160 ms was followed by a more frontally located (P3a: 240-310 ms) and a parietocentral positivity (P3b: 310-410 ms, highlighted) which was mostly pronounced at Pz. The probability of the event "other" (b) was 33% in block 1 and 66% in block 2. A frontocentral P3 at about 240-310 ms was followed by a parietal positivity at about 310-410 ms (highlighted).

The experimental P3b effects triggered by the manipulation of probability and expectancy regarding "self" and "other" events are illustrated in Figure 2. As suggested by the grand averages, P3b amplitudes are affected in the "exclusion" group, but not in the "expectancy-control" group.

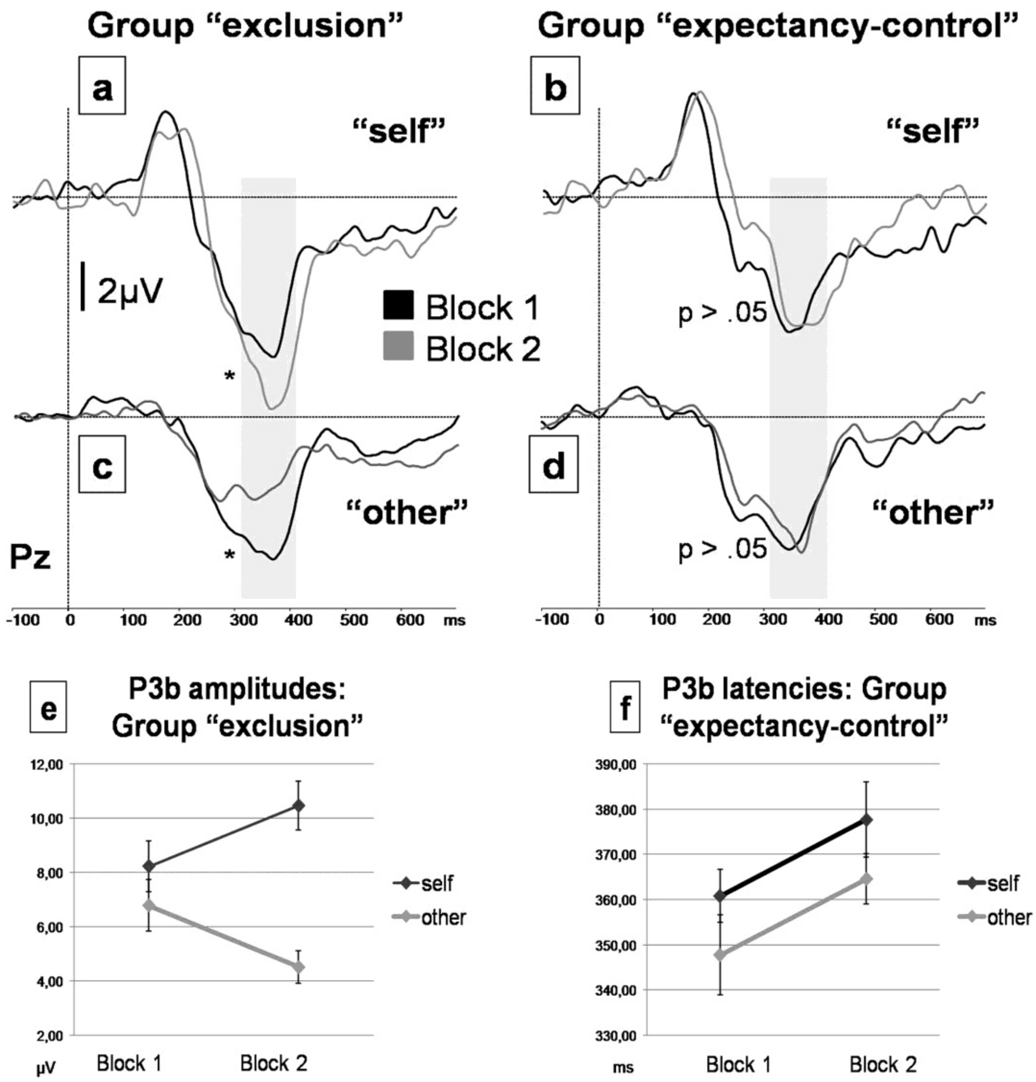


**Figure 2.** ERPs for the events "ball possession" (a, b) and "ball possession of a co-player" (c, d) for the two experimental groups ("exclusion": a, c; "expectancy-control": b, d) and conditions "block 1" (event "self": 33%, event "other": 33% probability), and "block 2" (event "self": 17%, event "other": 66% probability). Events were presented at 0 ms. Positive voltage is plotted downwards. *p*-values indicate differences between P3b peak amplitudes of the first and second block within experimental groups (* $p < .05$). e: P3b amplitudes for the "exclusion" group in the first and second block of the task for the events "self" and "other". f: P3b latencies for the "expectancy-control" group for the events "self" and "other".

Statistical analyses confirmed this impression: a 2 (ball possession: "self" vs. "other") x 2 (block: first block vs. second block) x 2 (group: "exclusion" vs. "expectancy-control") repeated measures ANOVA revealed a main effect of ball possession, $F(1,28) = 14.40$, $p = .001$, $\eta_p^2 = .34$, which was modulated by group and block, $F(1,28) = 4.98$, $p = .03$, $\eta_p^2 = .15$.

The following analyses were run separately for the groups. Descriptive data for the "exclusion" group (see Figure 2.e) suggest an amplitude enhancement for "self" trials, and a reduction for "other" trials from the first to the second block. This was statistically confirmed: in the "exclusion" group, there was a main effect of ball possession, $F(1,14) = 26.43$, $p < .001$, $\eta_p^2 = .65$, which was modulated by block, $F(1,14) = 12.87$, $p < .01$, $\eta_p^2 = .48$. Separate analyses for the "self" and "other" events revealed a significant enhancement of P3b amplitudes for "self" trials after the second block, $F(1,14) = 7.10$, $p = .02$, $\eta_p^2 = .34$, and a significant reduction for "other" trials, $F(1,14) = 7.62$, $p = .02$, $\eta_p^2 = .35$.

In the expectancy-control group, no effects were obtained (*p*s $\geq .21$).

**2.2.2 P3b latencies.** Grand averages suggest a latency shift in the "expectancy-control" group after the second block which was not visible in the "exclusion" group. Mean latencies for the "expectancy-control" group are depicted in Figure 2.f. A 2 (ball possession: "self" vs. "other") x 2 (block: first block vs. second block) x 2 (group: "exclusion" vs. "expectancy-control") repeated measures ANOVA revealed a main effect of block, $F(1,28) = 6.74$, $p = .02$, $\eta_p^2 = .19$, which was modulated by group, $F(1,28) = 6.22$, $p = .02$, $\eta_p^2 = .18$. Separate analyses for the groups confirmed a significant prolongation of P3b latencies in equal measures for both "self" and "other" events in the "expectancy-control" group (main effect of block: $F(1,14) = 10.89$, $p = .005$, $\eta_p^2 = .44$; interaction "block" x "ball possession": $F(1,14) < 001$, n.s.). For the exclusion group, no significant effects were obtained (*p*s $\geq .29$).

## 3. Discussion

In line with the hypotheses, our design evoked a dissociation between perceived probability of ball possession in the Cyberball game and the threat of social needs as measured by the NTQ: social exclusion was only induced in the "exclusion" group. If the expectancy of ball possession was adjusted by increasing the number of co-players ("expectancy-control" group), the questionnaire data were unaffected by reducing the probability of ball possession.

As expected, the reduced probability of ball possession (event "self") led to increased P3b amplitudes in the "exclusion" group. Analogously, the enhanced probability of the ball possession of the co-players (event "other") led to decreased P3b amplitudes in the "exclusion" group. In the "expectancy-control" group, no significant difference in P3b amplitudes was obtained between the two experimental blocks. In contrast, prolonged peak latencies after the second block were observed which held for both "self" and "other" events.

The questionnaire data confirm that exclusion in the Cyberball paradigm threatens fundamental social needs, as it was shown previously (e.g. Gonsalkorale & Williams, 2007; van Beest & Williams, 2006; Zadro, Williams & Richardson, 2004), and that partial exclusion is sufficient to induce this effect (Gutz et al., 2011; Williams et al., 2000): multiple comparisons show a significant reduction of belonging, meaningful existence, and control. The level of need threat is comparable to other studies (e.g. Bolling et al., 2011; Themanson et al., 2013). The non-significant reduction of self-esteem could be explained by the artificial character of the computer game which is probably less threatening than other forms of ostracism (Williams et al., 2002). It could also be caused by the insufficient statistical power due to the small sample size at least for questionnaire data which probably accounts for the non-significant interaction of the factors "group" and "block" for self-esteem and control.

The highly reliable effect of social exclusion on the need threat scale induced by reducing the probability of ball receptions can obviously be prevented by a simple manipulation of the setup: the addition of co-players demonstrates that a mere reduction of ball reception is not sufficient to elicit social need threat. The *a priori* probability of involvement considers the number of co-players, and any deviance from the resulting subjective expectancy affects the feeling of social inclusion.

The questionnaire data only provide indirect evidence for a rapid update of the subjective expectancy. The ERP data gave a more direct insight into the mechanism involved. As it was shown in our previous studies, ERP data confirmed that the P3b component is sensitive to ostracism manipulation in the Cyberball paradigm (Gutz et al., 2011; Weschke & Niedeggen, 2013). In the following we will discuss the underlying mechanisms which could be responsible for this effect.

Following Williams' model, the threat of social needs relies on the activation of the pre-attentive neural alarm system which triggers social pain (e.g. Williams, 2007). Although correlations between P3b amplitude and self-reported social pain or ostracism intensity were found in earlier studies (Gutz et al., 2011; Kawamoto et al., 2013), the neural generators are obviously different. As mentioned above, neuroimaging studies suggest that more frontal structures like parts of the ACC are involved in a "social pain" network. In contrast, the neural generator of the P3b is presumed to be a posterior network, including the parietal lobe, inferior temporal cortex, and the posterior part of the cingulate cortex (Bledowski et al., 2004; Wronka, Kaiser & Coenen, 2012). In addition, the P3b is rather a correlate of controlled information processing (Polich, 2007), and is probably not generated by a "preattentive" system.

Our results cannot rule out the existence of a pre-attentive neural alarm system. But we like to suggest that perceived social exclusion – as measured in the NTQ – are determined by a more cognitive process, namely expectancy violation.

In a recent ERP study, Kawamoto et al. (2013) found a decrease of P3b amplitudes over time during exclusion for the event "other" and a correlation between self-rated social pain and P3b amplitude in the first half of an exclusion condition. The authors interpreted the enhanced P3b amplitude for the event “other” as a correlate of a greater attentional focus on exclusionary cues which therefore led to greater social pain. Since the P3b amplitude diminished over time in the exclusion condition, it was concluded that self-relevance or stimulus probability account for that decrease. The correlation of social pain and P3b amplitude was in line with neuroimaging studies: in the dorsal anterior cingulate cortex (dACC), activity – presumed to be related to social pain – was larger in an initial phase of exclusion (Moor et al., 2012).

Our data are in agreement with the findings of Kawamoto et al. (2013), but the relation to social pain is questioned. In our study, we were not able to find reliable correlations between P3b amplitude and self-reported social pain[1]. In addition, as shown in Figure 1.b, the P3b amplitude triggered by the event “other” is a function of stimulus probability: the event “ball possession of the co-player” is more frequent in the exclusion condition, but less probable in the inclusion condition. This parallels the results of Kawamoto et al. (2013) on the P3b in the inclusion compared to the exclusion condition. Therefore, we suggest that the P3b effect can be related to a violation of expectancy: during continuous ostracism, not receiving the ball meets one’s expectation of exclusion, and occasionally receiving it contradicts them which are both reflected in the P3b amplitude of the event “self” and “other”. Similar effects can be found in the oddball paradigm: the lower the target probability, the higher the P3b amplitude. For non-target events, a mirror-image effect can be observed (Katayama & Polich, 1996; Rosenfeld, Biroschak, Kleschen & Smith, 2005).

The lack of the P3b effect in the “expectancy-control” group provides more evidence for the role of subjective expectancy which is detached from objective stimulus probabilities.

[1] We found isolated correlations between P3b amplitudes and some of the need scales which were all negative (the smaller the amplitude the greater self-reported social pain). Since correlations were not systematic and varied strongly depending on the methods of analysis (e.g. calculating correlations within blocks or using difference variables), we refrained from interpreting these barely reliable results.

Evidence is provided by stimulus sequence effects (Polich & Bondurant, 1997; Squires, Wickens, Squires & Donchin, 1976; Stadler, Klimesch, Pouthas & Ragot, 2006): within a serial presentation of stimuli, the P300/P3b response to the target is determined by the number of preceding non-target events. The P300/P3b amplitude is therefore also determined by the conditional probability of target occurrence – based on temporary expectation processes. Our design expands the modulating effect of subjective expectancy from temporary sequence effects to the number of different non-target events (here: co-players). The latter is considered in subjective expectancy, and compensates the effect of reduction of target (= ball possession) probability.

In the “expectancy-control” group, prolonged P3b latencies were found after the second block. P300 latencies are a correlate of stimulus evaluation time and are related to task difficulty and reaction times (Magliero, Bashore, Coles & Donchin, 1984; Polich, 1987). Since speeded response was not required in our experiment, possible differences in reaction times between the “exclusion” and “expectancy-control” groups could not be analyzed validly[2]. However, we conclude that the delayed peak latencies reflect the more complex setup in these conditions, e.g. discrimination between “self” and “other” events could be slightly more difficult because of the spatial arrangement of the positions, and there were more possibilities to react to the event “self” (Polich, 2007; Pritchard, Houlihan & Robinson, 1999; Smulders, Kok, Kenemans & Bashore, 1995).

Using ERPs for investigating social exclusion is a valuable approach because of its high temporal resolution. Future research should combine electrophysiological and imaging methods to integrate the findings. Following a multi-method approach, the application of a partial exclusion condition might be beneficial. This condition was shown to be sufficient to induce social need threat, and it also allows the analysis of occasional ball reception during

[2] Although speeded response was not required, reaction times were recorded. There were neither differences between blocks or experimental groups nor an interaction of the factors “block” and “group”.

exclusion. Differential activation within the ACC might clarify the structures related to social pain and/or expectancy processing. In our study, we focused on the cognitive aspects of the processing of social exclusion and we were able to differentiate the processing of objective stimulus probabilities and subjective expectancy. Therefore, our analyses were restricted to the parietal P3b. Midline ERPs (Figure 1) suggest that the effect of exclusion was mostly visible at Pz and in the time range of the P3b. Affective components are assumed to be more frontally located, for example in a frontal N2 (White, Wu, Borelli, Mayes & Crowley, 2013). In our study, there was no N2 visible for "other" events or any other specific frontal effects. However, we obtained a parietal N2 for "self" events. But this component was not affected by exclusion, and it was related to task relevance in a previous study (Gutz et al., 2011). Other studies found more frontally located effects in the slow-wave range (Crowley et al., 2009; Crowley et al., 2010). This could be due to methodological differences between studies (Themanson et al., 2015): the shortest time gap between relevant events was 900 ms in our design. Therefore, possible effects in a late time range could be superimposed by the ERPs of a following event.

Since ostracism is a complex social phenomenon, efforts should be made to distinctively investigate its components to identify emotional and cognitive processes which are either ostracism-specific or part of a more general network. Our results indicate that P3b amplitudes in the Cyberball paradigm rely on the expectation for the probability of both the event "self" ("ball possession of the participant") and the event "other" ("ball possession of a co-player"). Similar effects can be found in studies using the oddball paradigm, which suggests that this component is not part of an exclusion-specific neural alarm system, but reflects a more cognitive stage of processing which is sensitive to expectancy violations.

## 4. Experimental procedure

### 4.1 Participants

The procedure was approved by the local ethics committee at the FU Berlin. Thirty-nine healthy subjects participated in the experiment. Due to a high number of artifacts in the EEG, or incomplete questionnaire data, nine participants had to be excluded, leaving 30 for analyses. The participants had self-reportedly no history of psychiatric or neurological disorders and were not taking medication affecting the central nervous system. They were recruited in the university environment and gave their written consent for participating according to the Declaration of Helsinki. The subjects were randomly assigned to one of the two experimental groups ("expectancy-control": $n = 15$, seven female, mean age = 25.6 years; "exclusion": $n = 15$, seven female, mean age = 24.2 years). Since a cover story was required to induce the experimental effect, participants were informed about the experimental technique and aiming of the study afterwards. Participants got credit points for their studies, if desired.

### 4.2 Stimuli and Procedure

Matlab R2012a (TheMathWorks, Inc.) was used to present standardized instructions, the Cyberball game, and to trigger EEG recordings. The participants were told that they took part in a study testing visual imagination capabilities. To keep up this cover story, they first completed a short questionnaire about visual imagination (Vividness of Visual Imagery Questionnaire, Marks, 1973).

The setup (see Figure 3) followed an established ERP-compatible Cyberball design (see Gutz et al., 2011; Weschke & Niedeggen, 2013). Following the instructions and a short training introduction, participants of the two groups went through two experimental blocks. Each block consisted of 300 ball throws and lasted about ten minutes. Between the appearances of the ball at the players' positions, the ball appeared at the center of the screen for 500 ms. At the position "other" (= ball possession of a co-player, see Figure 3.b and d), the ball appeared for 400-1400 ms. The event "self" (see Figure 3.a and c) was defined as the appearance of the ball at the position assigned to the participant. The onset of this stimulus required the subjects to throw the ball to a co-player by pressing "2" (to the left co-player) or "3" (to the right co-player) during "three-player Cyberball", and "2", "3", "4", "5", or "6", in a clockwise arrangement, starting with the bottom left co-player during "six-player Cyberball" on a commercially available keyboard. No speeded response was required and there was no instruction regarding the fingers used for button presses.

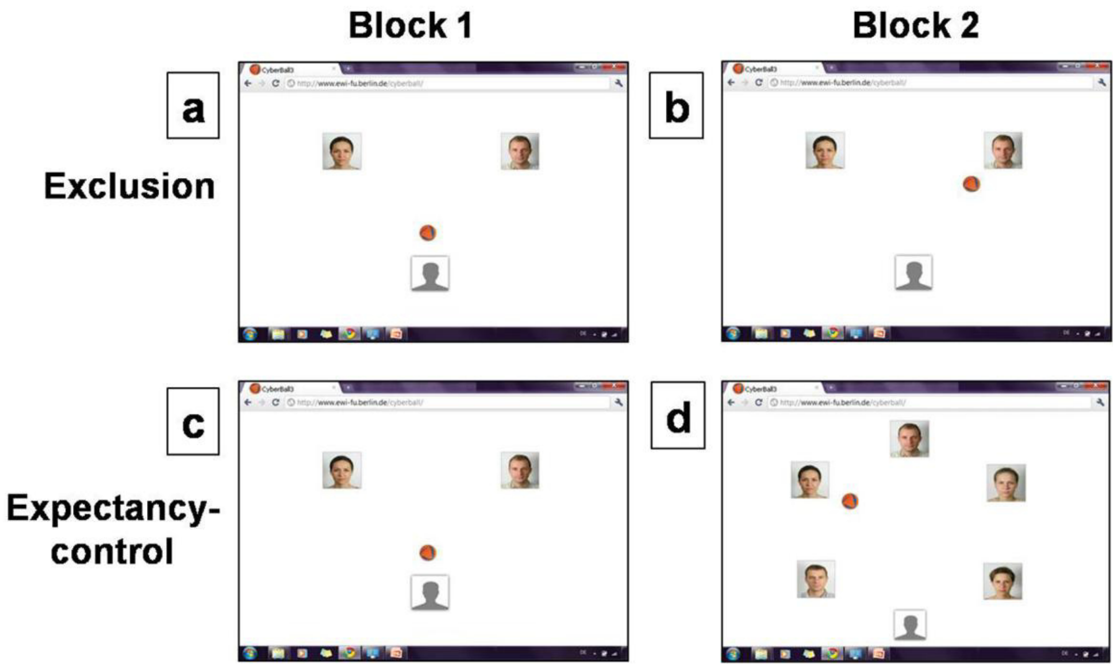


**Figure 3.** Display for the two groups in the first and second block of the game. In both groups, probabilities of the event "ball possession of participant" decreased from the first to the second block. In the "exclusion" group, the number of co-players remained constant between the two blocks (a, b), but in the "expectancy-control" group, there were two co-players in the first block (c), and five (d) in the second block of the task. Note that the pictures of the presumed co-players were no real photos, but morphs of different persons.

The objective probability of the event "self" was modulated in two successive blocks: in the first block, the probability of ball possession was 33 percent; in the second block, it was reduced to 17 percent. The events "other" were defined by the ball reception of a co-player. In order to exclude predictable events, the analysis of "other" events did not consider trials in which the ball was passed by the participant. Consequently, the probability of the (unpredictable) "other" events was 33 percent in the first and 66 percent in the second block. In the "exclusion" group, the number of co-players remained constant between the two blocks, resulting in an unfair distribution of ball possessions to the detriment of the participant in the second block. In the "expectancy-control" group, the number of players was enhanced from three to six (Figure 3.d), resulting in an even distribution of ball possession between the players despite the reduction of ball possession to 17 percent. Given that the participants took the number of co-players into account, the subjective expectation for the frequency of the event "self" was not violated.

The players were shown at equidistant positions on a circle line, and the position "self" was always on the bottom of the screen to control for a possible effect of position (Schoel, Eck & Greifeneder, 2014).

### 4.3 Self-reported data

To control for possible suspicion concerning the cover story, two Need Threat Questionnaires (NTQ, Williams et al., 2000) were handed out after the second block of the task. The participants were retrospectively asked how they felt during the first and the second block of the game (e.g. "I felt rejected."). The four need scales (belonging, self-esteem, meaningful existence, and control) had a possible range of 1 to 5. A German version of the NTQ was used (translation by Grzyb, 2005). The participants were also asked to estimate the probability of ball possession in the first and second block, respectively.

**4.4 EEG recording and analysis**

EEG data were recorded from 14 active electrode positions (Fp1, Fp2, F3, F4, F7, F8, FC5, FC6, C3, C4, AFz, Fz, Cz, Pz[3]) using Ag/AgCl skin electrodes. Active electrodes were referenced to linked earlobes with FCz serving as ground. Impedances were kept below 10 kΩ. Vertical and horizontal electrooculogram (< 20 kΩ) was recorded to control for ocular artifacts. Biosignals were recorded using a NuAmps Digital EEG amplifier and the recording software Aquire Applications 4.3.1 (both Compumedics, Neuroscan), then analyzed with BrainVision Analyzer 2 (Brain Products GmbH, Germany). Offline, data were band-pass filtered (0.3 to 30 Hz) and notch filtered (50 Hz). EEG segments were created (-100 to 700 ms after stimulus onset) and baseline-corrected (-100 to 0 ms). Subsequently, a semi-manual artifact rejection with individually adjusted amplitude criteria was performed, eliminating segments containing eye blinks, muscular or other artifacts, or high alpha activity. Analyses focused on segments defined by the appearance of the ball at the predefined positions ("self" or "other"), but neglected predictable events ("ball passed by the participant", see above). Since the number of the events "self" was higher in the first block (about 99 compared to 51 trials in the second block prior to artifact rejection), and the number of the events "other" was higher in the second block (about 198 compared to 102 trials in the first block prior to artifact rejection), the number of EEG segments was adjusted to the number of segments obtained in the respective other block by random selection. Averages and grand averages were calculated separately for the "self" and "other" events, the two experimental groups, and the two blocks of the game. For the "self" events, in the "exclusion" group $M = 34.9$ ($SD = 6.8$), and in the "expectancy-control" group $M = 30.1$ trials ($SD = 8.0$) were used for averaging. For the

[3] An early Cyberball ERP study (Crowley et al., 2009) found effects of ostracism at prefrontal leads. Therefore we also recorded signals from frontally located electrode positions despite our focus on the P3 complex which is presumably generated in a posterior network (Wronka et al., 2012). We did not find any ERP effects of social exclusion at prefrontal or frontal electrode positions separable from the P3 effect. This observation also held for average-referenced ERP data. Therefore results were not reported.

"other" events, in the "exclusion" group *M* = 67.4 (*SD* = 11.9), and in the "expectancy-control" group *M* = 67.3 trials (*SD* = 11.9) were used for averaging.

For the events "self" (see Figure 1.a), grand averaged ERPs revealed distinctive components: an initial posterior negativity (140 to 180 ms), followed by a frontocentral positivity (240-310 ms, P3a), and a subsequent positivity peaking at parietal leads (310 to 410 ms, P3b). The sequence of components replicated earlier findings (Gutz et al., 2011; Weschke & Niedeggen, 2013). Our experimental questions were specifically related to the P3b component, and analyses were concentrated on the Pz, as it was shown previously that the P3b is mostly expressed at this electrode position (Gutz et al., 2011; Kawamoto et al., 2013; Polich & Bondurant, 1997; Weschke & Niedeggen, 2013). Visual inspection of the grand averages revealed a latency shift from the first to the second block in the "expectancy-control" group (see Figure 2.b). Therefore, analyzing not only peak latencies, but also peak amplitudes instead of mean amplitudes in a predefined time segment was more appropriate. A semi-manual peak detection procedure identifying P3b peaks at Pz in a time range between 280 and 450 ms after stimulus appearance was performed, and peak latencies and baseline-to-peak amplitudes were identified.

For the events "other" (see Figure 1.b), the same sequence of positive components was elicited, but there was no preceding negativity. The grand averages revealed a frontocentral positivity at about 240-310 ms which was followed by a parietal positivity at about 310 to 410 ms. In order to compare the effects of probability and expectancy on both events, peak latencies and peak amplitudes of the parietal positivity were extracted and analyzed after a semi-manual peak detection procedure.

### 4.5 Data analysis

For each participant, mean peak amplitudes and peak latencies of the parietal P3b and data of the questionnaires were read into SPSS (version 21, IBM) and NTQ scales were computed. The four need scales were not merged into one overall need score as suggested by for example Bernstein and Claypool (2012), since the internal consistencies of the scales within conditions and groups were not satisfactory ($\alpha$ = .303-.772). Data were analyzed running repeated measures ANOVA including the within-subjects factor "block" (probability of ball possession 33% (block 1) vs. 17% (block 2); probability of ball possession of the co-players 33% (block 1) vs. 66% (block 2)), and the between-subjects factor "group" ("exclusion" vs. "expectancy-control"). For EEG data, the within-subjects factor "ball possession" ("self" vs. "other") was also included. After that, post-hoc tests were conducted.

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## 6.4 Eliminating social context in a Cyberball-like visual oddball task: ERP effects are independent of a feeling of exclusion

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**Full Title:** Eliminating social context in a Cyberball-like visual oddball task: ERP effects are independent of a feeling of exclusion

**Short Title:** Comparing the Cyberball and Oddball paradigm

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# Abstract

The phenomenon of social exclusion can be investigated by using a virtual ball-tossing game called Cyberball. In neuroimaging studies, structures have been identified which are activated during social exclusion. But to date the underlying mechanisms are not fully disclosed. In previous electrophysiological studies it was shown that the P3 complex is sensitive to exclusion manipulations in the Cyberball paradigm and that there is a correlation between P3 amplitude and self-reported social pain. Since this posterior event-related potential (ERP) was widely investigated using the oddball paradigm, we directly compared the ERP effects elicited by the task-relevant event in both paradigms ("target event" during Oddball and the event "ball possession" during Cyberball). Analysis focused on the effect of reducing the probability of the target event. In the first block, the probability of the task-relevant event was 33% (Cyberball: inclusion), in the second block it was reduced to 17% (Cyberball: exclusion). Our results indicate that ERP differences between inclusion and exclusion resemble ERP effects in a visual oddball task. We therefore conclude that P3 amplitudes in the Oddball and Cyberball paradigm rely on similar mechanisms, namely the probability of the task-relevant event. Since a social context was not necessary to induce the ERP effects, this component is not related to the activation of an exclusion-specific neural alarm system.


Keywords: social exclusion, Cyberball, Oddball, P3, probability

# Introduction

Social exclusion is a topic which got particular attention in recent years in both social psychology and neuroscience. The seminal model of Williams and colleagues (e.g. Williams, 2007; Williams & Zadro, 2001) states that four fundamental social needs – belonging, self-esteem, meaningful existence, and control – are immediately threatened by social exclusion. These researchers have developed the now widely used Cyberball paradigm, a virtual ball-tossing game in which participants are included or excluded by presumed, but actually computer-generated "co-players" (Williams, Cheung & Choi, 2000; Williams & Jarvis, 2006). This paradigm is particularly able to induce need threat (Bernstein & Claypool, 2012), which is retrospectively measured by the Need Threat Questionnaire (NTQ, Williams et al., 2000), and it was frequently used in both behavioral and neuroimaging studies.

The first fMRI studies using the Cyberball paradigm (Eisenberger & Lieberman, 2004; Eisenberger, Lieberman & Williams, 2003) found activation in the dorsal anterior cingulate cortex (dACC) and the anterior insula during social exclusion. These areas are also involved in the processing of physical pain (Rainville, Duncan, Price, Carrier & Bushnell, 1997). The "social/physical pain overlap theory" was supported by behavioral (Eisenberger, Jarcho, Lieberman & Naliboff, 2006) and pharmacological studies (see Eisenberger, 2012, for a review). However, critical voices emerged, stating that it can neither be concluded that social pain is experienced like physical pain nor that the overlapping activation pattern represents a pain-specific network. It was suggested that these areas are part of a "saliency network" or that they represent the processing of expectancy violations (Iannetti, Salomons, Moayedi, Mouraux & Davis, 2013; Somerville, Heatherton & Kelley, 2006). A meta-analysis showed that structures reliably activated during exclusion signaled social uncertainty, rumination, distress, and craving, but not social pain *per se* (Cacioppo et al., 2013). An alternative explanation for overlapping activation during physical and social pain was given by a recent study: although there are common activation patterns which were found by using gross analysis procedures, multivariate pattern analysis revealed subregions within these structures which were independently activated during physical pain and social rejection. Since these subregions have distinct functional connectivity patterns with other brain regions, it was concluded that pain and rejection distress are distinct types of affect (Woo et al., 2014).

Beside neuroimaging studies there are also electrophysiological studies which took advantage of the Cyberball paradigm (e.g. Crowley et al., 2009; Gutz, Küpper, Renneberg & Niedeggen, 2011; Kawamoto, Nittono & Ura, 2013; Themanson, Khatcherian, Ball & Rosen, 2013; Weschke & Niedeggen, 2013). If the ball was passed from one co-player to another, these events triggered a typical sequence of event-related potentials: a negative peak at approximately 200 ms (N2) followed by a more sustained positivity peaking at about 350 ms (P3). Within the conceptual framework defined by Williams and colleagues, the components were associated with the activation of the neural alarm system (Crowley, Wu, Molfese & Mayes, 2010; Kawamoto et al., 2013; Themanson et al., 2013). Moreover, some results revealed a correlation between the P3b amplitude and perceived ostracism intensity or social pain (Gutz et al., 2011; Kawamoto et al., 2013; Themanson et al., 2015). But – corresponding to the fMRI research – the functional assignment of ERP components to social exclusion, and the neural alarm system is questionable.

We suggest that it is more likely that the effects in the P3 range are mediated by the probability of ball possession or – more precisely – by the expectancy for ball possession (Weschke & Niedeggen, 2015). In ERP literature, the processing of expectancy and stimulus probabilities is usually examined by using an oddball paradigm (Duncan-Johnson & Donchin, 1977; Polich & Margala, 1997). Here, the frequency of a task-relevant event is varied systematically. Following this approach, we used a partial exclusion condition in our previous studies allowing a separate analysis of ERP responses to the event “self” (= ball possession of the participant). In line with an early Cyberball study (Williams et al., 2000), partial exclusion was found to be sufficient to trigger need threat and negative feelings (Gutz et al., 2011). Transferring the terms of the Cyberball to the oddball paradigm, the event “self” served as target stimulus because it requires a reaction from the participant, whereas the event “other” (= ball possession of a co-player) served as standard or non-target stimulus. In line with the established ERP signatures identified in the oddball paradigm (Katayama & Polich, 1996), the parietal P3 (P300 or P3b) amplitudes were larger for target stimuli (event “self”) compared to non-targets (event “other”) (Gutz et al., 2011; Themanson et al., 2015). For the event “self”, the amplitude of the P3 complex (with a central P3a and a parietal P3b component) was affected by stimulus probability or expectancy for target appearance (Donchin, 1981; Gutz et al., 2011; Weschke & Niedeggen, 2013). Similar ERP components were found to be modulated in independent Cyberball studies where analysis was focused on the events “other” (Kawamoto et al., 2013; Themanson et al., 2013).

The striking similarity of ERP signatures triggered in the Cyber- and the oddball paradigm leads itself to the question whether a common process is triggered. Our aim was to further prove our interpretation of the ERP effects of exclusion in the Cyberball paradigm. Therefore we directly compared these two paradigms in the current study: we designed a visual oddball task which was physically identical to our ERP-compatible Cyberball paradigm (see Weschke & Niedeggen, 2013, condition "Presence"), but the social context was eliminated as participants assumed to take part in a simple reaction experiment. In a standard Cyberball condition, participants were told that they would play a ball-tossing game with other co-players connected via internet. Data of this condition have already been presented in (Weschke & Niedeggen, 2013) (Internet group). Here, they serve as a control for the effects in the Oddball group. Participants of both groups ran through two consecutive blocks, with the second block defined by a decrease in target probability.

We suppose that the social cover story provided in the Cyberball design will specifically affect the retrospective evaluation in a questionnaire, but not the “online” processing of subjective expectancies. We propose that a feeling of ostracism will not emerge when the social context of the task is removed (group “Oddball”). Only in the Cyberball task a reduction of target probability (“ball possession”) is expected to induce social need threat and to increased negative mood.

As we have shown in our previous studies (Gutz et al., 2011; Weschke & Niedeggen, 2013), the event “self” in Cyberball evokes two distinct ERP components. We hypothesize that the same components will be identified if target events are presented in the Oddball paradigm.

The first component was a parietal N2 which was interpreted as a correlate of task relevance (Wijers et al., 1987): it was more pronounced after the event “self” which demands a motor reaction from the participant compared to the event “other”, but the amplitude did not differ between inclusion and exclusion (Gutz et al., 2011). Therefore this component should also not be influenced by the probability of the task-relevant target stimulus.

The second component was a P3 complex, consisting of a central P3a and a parietal P3b. Earlier results showed that these components are sensitive to ostracism manipulation in the Cyberball paradigm (Gutz et al., 2011; Kawamoto et al., 2013; Weschke & Niedeggen, 2013). Although a correlation between P3a and negative mood, and P3b and ostracism intensity was found in one study (Gutz et al., 2011), we have not been able to replicate these results. We therefore propose that the ERP effects in the P3 range in the Cyberball and a visual oddball task rely on the same mechanism, namely the expectancy for target appearance (or ball reception), and expect similar effects of target probability on the P3 complex.

By directly comparing the ERPs elicited by task-relevant stimuli in the Cyberball and Oddball task, we also have the opportunity to check if there any components or experimental effects which are specifically evoked in one of the two paradigms.

# Materials and Methods

## Participants

Twenty-one healthy subjects took part in the Oddball task. Due to a high number of artifacts in the EEG or missing questionnaire data, six participants had to be excluded, leaving fifteen (10 female) for analyses. Their mean age was 21.7 years (*SD* = 2.9 years). In the Cyberball task, eighteen subjects took part. Three of them had to be excluded, leaving fifteen (7 female) for analyses. Their mean age was 24.7 years (*SD* = 6.8 years). Age did not differ significantly between groups, $F(1,28) = 2.47$, $p = .128$. The procedure was approved by the ethics committee of Freie Universität Berlin (Ethikkommission der Freien Universität Berlin). Participants were recruited in the university environment and got credit points for their studies, if desired. They gave their written consent for participating according to the Declaration of Helsinki. Since a cover story was required to induce the experimental effect in the Cyberball task, participants were informed about the experimental technique and aiming of the study immediately after the experiment. After that they again gave their written consent for participation.

## Stimuli and procedure

E-Prime 2 (Psychology Software Tools, Inc.) was used to present standardized instructions, the visual Oddball or the Cyberball task, and to trigger EEG recordings. The participants in the Cyberball group were told that they took part in a study testing visual imagination capabilities. To keep up this cover story, they first completed a short questionnaire about visual imagination (Vividness of Visual Imagery Questionnaire, Marks, 1973). The participants in the Oddball group were informed that they were taking part in a simple reaction experiment.

The setup for the Cyberball group (see Fig 1.a) had been described already in our previous paper (Weschke & Niedeggen, 2013: Cyberball Internet group). For the Oddball group, photos of presumed co-players were replaced by single letters at the corresponding positions (see Fig 1.b). A physically identical display had also been used in our previous study (Weschke & Niedeggen, 2013: Cyberball Presence group).

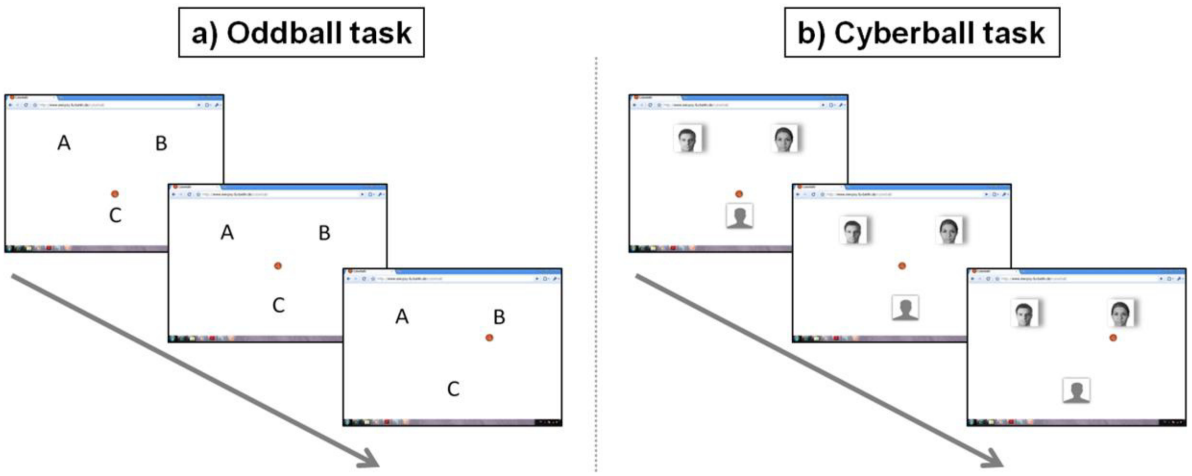


**Fig 1. Display of the visual Oddball (a) and the Cyberball (b) task.**

The events "circle at position 'C'" (Oddball) or "ball possession of the participant" (Cyberball) were defined as target events, since they required the participant to press a button to move the circle/ball to the position "A" or "B" or to the left or right co-player. Before the circle/ball appeared at the selected position, it remained at the center of the screen for 500 ms. At the positions "A" or "B" or at one of the co-players' position (non-target events) the circle/ball remained for 400 to 1400 ms, and the participant was not required to react. Note that the pictures of the presumed co-players (b) were no real photos, but morphs of different persons.

After instructions and a short training introduction, participants of both groups went through two experimental blocks. There was a short break between the blocks. Each block consisted of 200 trials and lasted about seven minutes. One trial was defined as the appearance of a red circle that symbolized a ball in the Cyberball task at one of the designated positions (target or non-target, see Fig 1). The circle appeared in the center of the screen for 500 ms between target and non-target events. At a non-target position (position “A” or “B” or “ball possession of a co-player”), the circle remained for 400-1400 ms before it moved back to the center and then to the other non-target or to the target position. The target event was defined as the appearance of the circle at position “C” (Oddball) or at the position assigned to the participant (Cyberball). The onset of this stimulus required the subject to move the circle to another position by button press (“g” to move the circle to position “A” or to the left co-player, and “h” to move the circle to “B” or to the right co-player) on a commercially available keyboard. No speeded response was required.

In the first block, the probability of the target event was 33 percent (“Inclusion”), in the second block it was reduced to 17 percent (“Exclusion”). This parallels our previous work (Gutz et al., 2011; Weschke & Niedeggen, 2013).

After the second block, two Need Threat Questionnaires were handed out. The subjects were told to retrospectively fill out the questionnaires, the first one regarding the first block, and the second one regarding the second block. A German version of the NTQ was used (translation by Grzyb, 2005). Some items (e.g. “I felt like an outsider.” “I felt rejected.”) of this questionnaire are not appropriate for a non-social oddball task, and hence the validity is disputable. However, we decided to also apply it to the Oddball group to control for possible effects. There is evidence that need threat is evoked even in a situation where the participants knew that their co-players were computer-generated (Zadro, Williams & Richardson, 2004). The participants were also asked to estimate the probability of the target stimulus (Cyberball: “ball possession”; Oddball: “circle at position ‘C’”) in the first and second block, respectively.

## EEG recording and analysis

EEG data were recorded from three active electrode positions (Fz, Cz, Pz) using Ag/AgCl skin electrodes which were fixed on the scalp with EC2 Electrode Cream (Grass Technologies). Active electrodes were referenced to linked earlobes with AFz serving as ground. Impedances were kept below 10 kΩ. Vertical and horizontal electrooculogram (< 20 kΩ) was recorded to control for ocular artifacts. Biosignals were recorded with EEG BioAmplifiers and Psylab recording software (Contact Precision Instruments, London) and analyzed with BrainVision Analyzer 2 (Brain Products GmbH, Germany). Data were band-pass filtered (0.3 to 30 Hz) and notch filtered (50 Hz) offline. EEG segments were created (-100 to 800 ms after target onset, separately for the first and the second block) and baseline-corrected (-50 to 50 ms after target onset). Subsequently, a semi-manual artifact rejection was performed, eliminating segments containing eye blinks, muscular or other artifacts, or high alpha activity. Since there were more target events in the first block, the number of EEG segments was randomly chosen to adjust it to the number of segments obtained in the second block. Averages and grand averages were calculated separately for the two tasks, two blocks, and three electrode positions. Our analyses focused on target events to compare the results with our previous Cyberball study where we analyzed the events "ball possession of the participant" (Weschke & Niedeggen, 2013). Therefore we did not report the ERPs elicited by the non-target events. However, our data suggest that in both paradigms the parietal N2 component was more pronounced after target events compared to non-target events (see also Gutz et al., 2011).

Grand-averaged ERPs revealed three distinctive components in both groups (see Fig 2): an initial posterior negativity (130 to 210 ms, N2), followed by a P3 complex with a central positivity at 240-300 ms (P3a), and a subsequent parietal positivity (300 to 410 ms, P3b). Sequence and time ranges of ERP components elicited in the Oddball group replicated our earlier Cyberball results (Gutz et al., 2011; Weschke & Niedeggen, 2013). The visual inspection of the ERPs elicited by the target stimuli did not reveal any components or effects which were specifically elicited in one of the two paradigms. Since Grand Averages suggest a latency shift of the N2 component from the first to the second block in the Cyberball group, we also conducted peak analyses. However, peak analyses as well as mean amplitudes in the defined time segment of the N2 did not reveal a significant effect of condition on N2 amplitudes. Therefore we decided to analyze mean values of all components of interest.

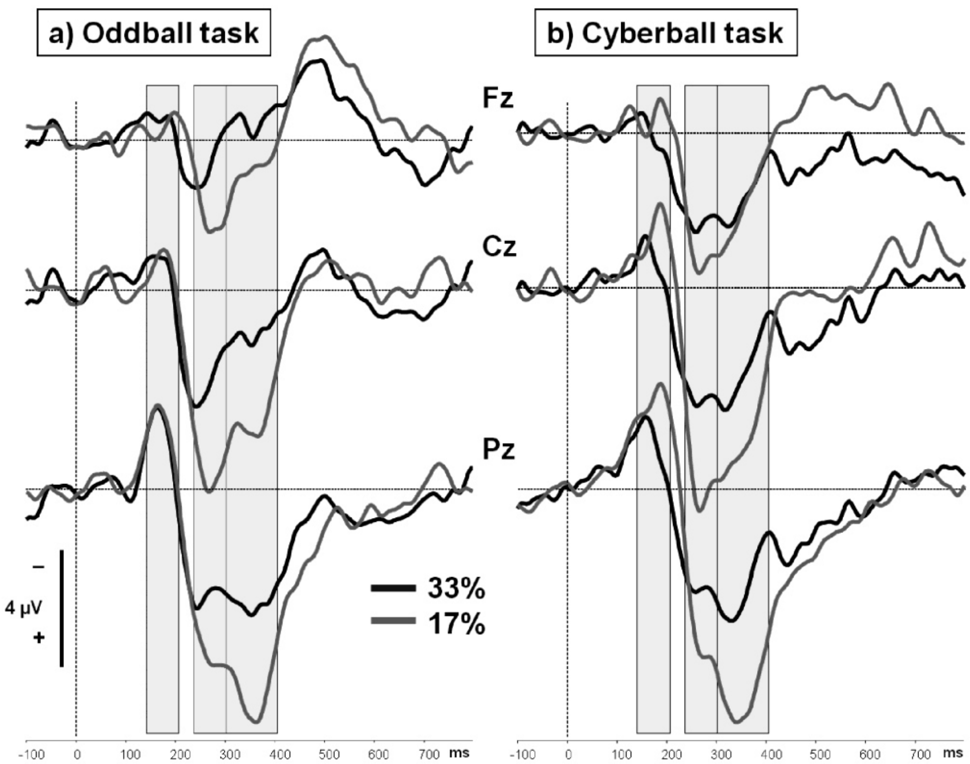


**Fig 2. Grand-averaged ERPs.**

Grand-averaged ERPs for the target event (a: Oddball task, circle at position "C"; b: Cyberball task, ball possession of the participant) in the first (33% target probability; black lines) and the second (17% target probability; grey lines) block of the tasks, recorded from the electrode positions Fz, Cz, and Pz. A parietal N2 (130-210 ms) was followed by a P3 complex with a centrally located P3a (240-300 ms) and a P3b (300-410 ms) with a parietal maximum. The target event was presented at 0 ms.

## Data analysis

For each participant, mean amplitudes of the components of interest (see above) were exported and read into SPSS (version 21, IBM). Furthermore, questionnaire data were entered in SPSS, and NTQ scales “belonging”, “self-esteem”, “meaningful existence”, and “control”, and an additional scale included in the NTQ measuring negative mood were computed (all items were rated on a 1 to 5 Likert scale, with need scales having a potential range between 1 and 5 and negative mood between 4 and 20). Data were analyzed running repeated measures ANOVA including the within-subjects factor “block” (target probability 33% (block 1) vs. 17% (block 2)) and – for ERP data – including the within-subjects factor “electrode position” (Fz vs. Cz vs. Pz) and the between-subjects factor “task” (Cyberball vs. Oddball). Multivariate tests will be reported.

# Results

## Questionnaire data

Participants noticed the difference of target occurrence between experimental blocks: In the Oddball group mean estimation of target probability was 28.2 percent (*SD* = 11.3%) for the first, and 18.7 percent (*SD* = 5.6%) for the second block of the task, which indicates a significant difference, $F(1,14) = 20.29$, $p < .001$, $\eta_p^2 = .59$. In the Cyberball group mean estimation of target probability was 30.5 percent (*SD* = 10.4%) for the first, and 12.9 percent (*SD* = 5.5%) for the second block of the task, which also indicates a significant difference, $F(1,14) = 40.36$, $p < .001$, $\eta_p^2 = .74$.

Descriptive data of the NTQ data for the Oddball and Cyberball group are presented in Table 1. As we had already reported in our previous paper (Weschke & Niedeggen, 2013), there was a significant decrease in need satisfaction for belonging, $F(1,14) = 19.64$, $p = .001$,

$\eta_p^2 = .58$, self-esteem, $F(1,14) = 4.89$, $p = .04$, $\eta_p^2 = .26$, and control, $F(1,14) = 7.21$, $p = .02$, $\eta_p^2 = .34$, and a nearly significant reduction for meaningful existence, $F(1,14) = 4.12$, $p = .06$, $\eta_p^2 = .23$, after exclusion in the Cyberball group. Negative mood significantly increased after the second block, $F(1,14) = 21.99$, $p < .001$, $\eta_p^2 = .61$. In the Oddball group, a significant difference between blocks was obtained in none of the scales (belonging: $F(1,14) = 0.63$, $p = .44$, $\eta_p^2 = .04$; self-esteem: $F(1,14) = 4.35$, $p = .06$; $\eta_p^2 = .24$, meaningful existence: $F(1,14) = 0.02$, $p = .89$, $\eta_p^2 = .001$; control: $F(1,14) = 1.15$, $p = .30$, $\eta_p^2 = .08$, negative mood: $F(1,14) = 0.69$, $p = .42$, $\eta_p^2 = .05$).

**Table 1. Questionnaire data of the Oddball and Cyberball group for the two experimental blocks.**

| | **Oddball** | | **Cyberball** | |
|---|---|---|---|---|
| | **Block 1** | **Block 2** | **Block 1** | **Block 2** |
| **Belonging** | 4.11 (0.70) | 3.98 (1.00) | 3.80 (0.58) | 2.53 (0.92) |
| **Self-esteem** | 3.36 (0.54) | 3.18 (0.60) | 3.60 (0.61) | 3.18 (0.50) |
| **Meaningful existence** | 4.38 (0.82) | 4.36 (0.85) | 4.27 (0.83) | 3.60 (1.09) |
| **Control** | 2.36 (0.90) | 2.20 (0.71) | 2.31 (0.70) | 1.67 (0.74) |
| **Negative mood** | 9.40 (2.66) | 9.80 (2.42) | 8.53 (2.53) | 12.60 (2.75) |

Mean values and standard deviations (in brackets) are presented.

# ERP data

The grand-averaged ERPs evoked by the target event in both tasks and experimental blocks are depicted in Fig 2. In both tasks, similar components were elicited by target appearance. Three time ranges were exported for further analyses: the N2 range (130 to 210 ms), the P3a range (240 to 300 ms), and the P3b range (300 to 410 ms). The same time ranges were also analyzed in our previous paper (Weschke & Niedeggen, 2013).

## N2 (130-210 ms)

The N2 component elicited by the presentation of the target stimulus was clearly visible in both blocks of the task, and mostly pronounced at Pz (main effect of electrode position, $F(2,27) = 9.27$, $p = .001$, $\eta_p^2 = .41$). There was neither a main effect of task, $F(1,28) = 0.11$, $p = .74$, or block, $F(1,28) = 1.20$, $p = .28$, nor an interaction of the factors "block" and "task", $F(1,28) = 1.03$, $p = .32$. Grand averages suggest an increased amplitude in the second block of the Cyberball task, but this was not statistically confirmed (analyses separate for electrode positions $p$s $\geq .106$).

## P3a (240-300 ms)

The earlier part of the P3 complex elicited by the target stimulus was most prominent at centro-parietal leads (main effect of electrode position: $F(2,27) = 29.76$, $p < .001$, $\eta_p^2 = .69$) and more pronounced in the second block (main effect of block: $F(1,28) = 7.46$, $p = .01$, $\eta_p^2 = .21$). There was no main effect of task, $F(1,28) = 0.56$, $p = .46$, but the effect of block was significantly modulated by electrode position, $F(2,27) = 9.44$, $p = .001$, $\eta_p^2 = .41$. Separate analysis revealed a main effect of block at Cz, $F(1,28) = 10.82$, $p = .003$, $\eta_p^2 = .28$, and Pz, $F(1,28) = 5.37$, $p = .03$, $\eta_p^2 = .16$, but not at Fz, $F(1,28) = 3.95$, $p = .057$. These effects were not modulated by the factor "task" at neither electrode position ($p$s $\geq .869$).

## P3b (300-410 ms)

The P3a was followed by a P3b component, mostly pronounced at Pz (main effect of electrode position: $F(2,27) = 30.64$, $p < .001$, $\eta_p^2 = .69$). A significant main effect of block indicates that the amplitude was higher in the second block of the tasks, $F(1,28) = 20.44$, $p < .001$, $\eta_p^2 = .42$. There was no main effect of task, $F(1,28) = 1.62$, $p = .21$, but also the effect in the P3b range was modulated by electrode position, $F(2,27) = 11.36$, $p < .001$, $\eta_p^2 = .46$. Separate analyses for the electrode positions revealed an effect of block at Cz, $F(1,28) =$

18.66, $p < .001$, $\eta_p^2 = .40$, and Pz, $F(1,28) = 34.64$, $p < .001$, $\eta_p^2 = .55$, but not at Fz, $F(1,28) = 3.47$, $p = .073$. These effects were not modulated by the factor "task" ($p$s $\geq .566$).

# Discussion

## Summary of results

In line with the hypotheses, the reduction of target probability did not lead to increased feelings of exclusion or negative mood in the Oddball task as it did in the Cyberball task. At the same time, participants of both groups were able to notice the difference of target probabilities between the two blocks. The relevant target event triggered an N2/P3 complex in both paradigms. Reduced target probability did not affect the N2 amplitude, but increased P3a and P3b amplitudes in both the Oddball and Cyberball task. It shows that the ERP effects are independent from social context or perceived social exclusion. We did not find any specific components or experimental effects which were restricted to one of the tasks.

## Questionnaire data

In Cyberball studies, social exclusion is defined by reducing the probability of ball receptions which led to perceived ostracism in total (e.g. Eisenberger et al., 2003; Themanson et al., 2013) and partial (e.g. Gutz et al., 2011; Williams et al., 2000) exclusion paradigms. The data of the Cyberball group replicated these results: after exclusion, participants reported a decrease of need satisfaction and an increase of negative mood. However, the reduction of the scale "meaningful existence" did not reach significance. Although there are reports that not all needs are similarly affected in paradigms using computer-mediated communication (Williams et al., 2002), we suggest that this missing effect is due to the small sample size at least for questionnaire data.

On the contrary, the results of the visual Oddball task show that by eliminating the social context, reduced target probability – which was clearly noticed by the participants – did not lead to a feeling of social exclusion. Although there is evidence that the credibility of the cover story or the source of exclusion have minimal influence on the induction of social need threat during Cyberball (Weschke & Niedeggen, 2013; Zadro et al., 2004), the complete removal of the social context eliminated the robust exclusion effect.

## ERP data

A direct comparison of ERP results in the Cyberball task and the Oddball task showed that the processing of the task-relevant stimulus (“target event” in the Oddball task, and “ball possession” in the Cyberball task) did not differ: two components were elicited by the presentation of this event: a parietal N2, and a P3 complex constituted by a central P3a and a parietal P3b.

Since the N2 component was not affected by the reduction of target probability, we suggest that this component reflects task relevance or target detection: it was shown previously that targets compared to non-target and ball receptions compared to non-ball receptions elicited a posterior N2 (Bocquillon et al., 2014; Gutz et al., 2011; Wijers et al., 1987). This component is not sensitive to the probability of a task-relevant event (Gutz et al., 2011; Weschke & Niedeggen, 2013). The similarity of the N2 components elicited in both the Cyberball and Oddball group also indicates that the relevance of the target stimulus does not differ between paradigms.

The effects of target probability on the P3 complex in the visual oddball task were similar to the effects obtained during Cyberball (Gutz et al., 2011; Weschke & Niedeggen, 2013). The P3 complex in our previous studies was divided into a central P3a and a parietal P3b (Gutz et al., 2011; Weschke & Niedeggen, 2013). The P3a effect was correlated with an increase in negative mood after experiencing social exclusion. The P3b effect was correlated with an increase in perceived ostracism intensity (Gutz et al., 2011), social pain (Kawamoto et al., 2013), or an decrease in positive affect and control (Themanson et al., 2013). In this study, the early and late part of the P3 did not show a distinctive topography, and they were both related to stimulus probability. Therefore, both parts of the P3 complex will be discussed as a functional unit.

In an earlier Cyberball study, the P3b triggered by the event “ball possession of a co-player” (= non-target event) was more pronounced during inclusion compared to exclusion (Kawamoto et al., 2013). The authors interpreted the enhanced P3 amplitude as a correlate of a greater attentional focus on exclusionary cues which therefore led to greater social pain. Since the P3b amplitude diminished over time in the exclusion condition, it was concluded that self-relevance or stimulus probability account for that decrease. We suggest that the P3 amplitude triggered by this event is a function of stimulus probability: the event “ball possession of the co-player” is more frequent in the exclusion condition compared to the inclusion condition. P3 amplitudes are in close relation with target probabilities (Polich & Criado, 2006; Squires, Squires & Hillyard, 1975): The lower the target probability, the higher the P3 amplitude. Similar results were obtained not only in oddball studies for non-target events (Katayama & Polich, 1996; Rosenfeld, Biroschak, Kleschen & Smith, 2005), but were recently replicated for the event “ball possession of the co-player” in a Cyberball study (Weschke & Niedeggen, 2015).

The probability effect is also in line with the ERPs on the event “ball possession of the participant” (event “self”), which is less probable during exclusion compared to inclusion. During continuous ostracism, not receiving the ball meets one’s expectation of exclusion, and occasionally receiving it contradicts them which are both reflected in the P3b amplitude of the event “self” and “other” (Weschke & Niedeggen, 2015). Additional evidence is given by a recent Cyberball study with a clinical sample: the more the current expectancy for involvement was violated by receiving the ball, the more the P3 amplitude was pronounced (Gutz, Renneberg, Roepke & Niedeggen, 2015).

The findings of the Oddball task question the relation of the ERP effects to need threat, since the effects in the P3 range are not necessarily associated with the experience of social exclusion: there was no decrease in need satisfaction or an increase in negative mood after the second block of the Oddball task. The P3 effect rather corresponds to the estimation of target probability and the expectancy for target appearance, which can therefore serve as the most parsimonious explanation within the Cyberball paradigm.

Ostracism is a complex social phenomenon, but some of the underlying mechanism can rely on basal cognitive functioning. Efforts should be made to distinctively investigate these mechanisms to identify emotional and cognitive processes which are either specifically "social" or part of a more general network. Our data show that the P3 effects are not related to the activation of an exclusion-specific neural alarm system (Gutz et al., 2011; Williams & Zadro, 2001) because they can also be elicited by a physically similar, but non-social visual oddball task. They rather seem to reflect basal cognitive functions and thereby in line with alternative explanations for the neural effects of exclusion obtained in fMRI studies (Iannetti et al., 2013; Somerville et al., 2006). This also fits well into a recently proposed theory which states that both low level (e.g. in Stroop tasks) and high level (e.g. cognitive dissonance) inconsistencies, i.e. deviations from current expectancies, are detected by a common neuronal network  (Proulx, Inzlicht & Harmon-Jones, 2012). In this context, it is not surprising that the electrophysiological effects of the reduction of target probabilities do not differ between the simple attention task (Oddball) and the more complex simulation of a social interaction (Cyberball).

# Conclusion

Our data show that ERP amplitudes in the N2 and P3 range are independent from social context or perceived social exclusion. The results indicate that the effects on the P3 complex in the Cyberball paradigm and a visual Oddball task rely on similar mechanisms: the relationship between P3 effects and the experience of ostracism seems to be mediated by the perception of the probability of a task-relevant stimulus.

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# 7. Anteilserklärung

1. Weschke, S. & Niedeggen, M. (2013). The effect of the physical presence of co-players on perceived ostracism and event-related brain potentials in the cyberball paradigm. *PLoS One, 8*(8). doi: http://dx.doi.org/10.1371/journal.pone.0071928

- Entwicklung der Konzeption (mehrheitlich)
- Literaturrecherche (mehrheitlich)
- Versuchsdesign (in Teilen)
- Datenerhebung (vollständig)
- Datenauswertung (mehrheitlich)
- Ergebnisdiskussion (mehrheitlich)
- Anfertigung der ersten Version des Manuskripts (vollständig)

2. Niedeggen, M., Sarauli, N., Cacciola, S. & Weschke, S. (2014). Are there benefits of social overinclusion? Behavioral and ERP effects in the Cyberball paradigm. *Frontiers in Human Neuroscience, 8*(935). doi: http://dx.doi.org/10.3389/fnhum.2014.00935

- Entwicklung der Konzeption (in Teilen)
- Literaturrecherche (mehrheitlich)
- Versuchsdesign (in Teilen)
- Datenauswertung (in Teilen)
- Ergebnisdiskussion (in Teilen)
- Korrektur des Manuskripts (mehrheitlich)

3. Weschke, S. & Niedeggen, M. (2015). ERP effects and perceived exclusion in the Cyberball paradigm: correlates of expectancy violation? *Brain Research*, epub ahead of print. doi: http://dx.doi.org/10.1016/j.brainres.2015.07.038

- Entwicklung der Konzeption (mehrheitlich)

- Literaturrecherche (mehrheitlich)
- Versuchsdesign (mehrheitlich)
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- Ergebnisdiskussion (mehrheitlich)
- Anfertigung der ersten Version des Manuskripts (vollständig)
- Einreichung des Manuskripts (mehrheitlich)

4. Weschke, S. & Niedeggen, M. (submitted). Eliminating social context in a Cyberball-like visual oddball task: ERP effects are independent of a feeling of exclusion. *PLoS One*.

- Entwicklung der Konzeption (mehrheitlich)
- Literaturrecherche (mehrheitlich)
- Versuchsdesign (in Teilen)
- Datenerhebung (vollständig)
- Datenauswertung (mehrheitlich)
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- Anfertigung der ersten Version des Manuskripts (vollständig)
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Sarah Weschke Michael Niedeggen

# 8. Eidesstattliche Erklärung

**Eidesstattliche Erklärung nach § 7 Abs. 4 der Gemeinsamen Promotionsordnung zum Dr. phil. / Ph.D. der Freien Universität Berlin vom 2. Dezember 2008:**

Hiermit erkläre ich, dass ich die vorliegende Arbeit selbstständig und ohne die (unzulässige) Hilfe Dritter verfasst und nur die angegebenen Quellen und Hilfsmittel benutzt habe. Weiterhin erkläre ich, dass die Dissertation weder in Teilen noch in ihrer Gesamtheit einer anderen wissenschaftlichen Hochschule zur Begutachtung in einem Promotionsverfahren vorliegt oder vorgelegen hat.

Datum

Unterschrift

# Anhang

## Anhang 1: Items und Skalen des Need-Threat-Questionnaire

**Tabelle 1:** Items und Skalen des NTQ (Williams et al., 2000; deutsche Übersetzung von Grzyb, 2005).

| **Skala** | **Items** | |
|---|---|---|
| Zugehörigkeit | 1: Ich fühlte mich „unverbunden“ mit den anderen. (umkodiert)<br>2. Ich fühlte mich zurückgewiesen. (umkodiert)<br>3: Ich fühlte mich wie ein Außenseiter. (umkodiert) | |
| Selbstwert | 4: Ich fühlte mich gut.<br>5: Ich hatte ein gutes Selbstwertgefühl.<br>6: Ich fühlte mich beliebt. | |
| Sinn der eigenen Existenz | 7: Ich fühlte mich unsichtbar. (umkodiert)<br>8: Ich fühlte mich bedeutungslos. (umkodiert)<br>9: Ich fühlte mich nicht existent. (umkodiert) | |
| Kontrolle | 10: Ich fühlte mich mächtig.<br>11: Ich hatte Kontrolle über den Ablauf der Interaktion.<br>12: Ich fühlte mich überlegen. | |
| Aversive Impact Index | Kohäsions-Wahrnehmung | 3: Ich fühlte mich wie ein Außenseiter.<br>6: Ich fühlte mich beliebt. (umkodiert) |
| | Negative Stimmung | 13: gut (umkodiert)<br>14: schlecht<br>15: freundlich (umkodiert)<br>16: unfreundlich<br>17: ärgerlich<br>18: traurig<br>19: angespannt<br>20: entspannt (umkodiert) |
| | Ostrazismus-Intensität | 21: Ich wurde nicht beachtet.<br>22: Ich wurde ausgeschlossen. |
| Einschätzung Ballerhalt | Wenn der Ball gleich häufig zu jeder Person geworfen wird, bekommt (bei drei Spielern) ein Spieler 33% der Würfe. Wie viel Prozent der Würfe haben Sie bekommen? | |

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