

#### 4. DISCUSSION

The main aim of the present dissertation was to investigate the development of goal-directed interpersonal action synchronization across the lifespan. More specifically, I investigated person characteristics that may underlie the ability to synchronize own actions with those of others as well as consequences of interpersonal synchronization accuracy for interpersonal experience from a lifespan-developmental perspective (e.g., P. B. Baltes, 1987, 1990). I proposed a theoretical model that frames the development of interpersonal action synchronization as being based on individual competencies that can be related to two global components of lifespan development, that is, *life mechanics* and *life pragmatics*. Age-related differences in the ability to synchronize one's own actions with others' were further assumed to be observable in interpersonal action synchronization between individuals of same- and mixed ages. Referring to *dyads* as the smallest unit of social interaction, I specified the following three research questions for the present empirical study:

1. How do individual and age-related differences in sensorimotor abilities and social competencies relate to dyadic action synchronization?
2. Do dyads of varying age compositions differ in dyadic action synchronization?
3. How does the accuracy of dyadic action synchronization affect individuals' subjective experience of the situation and the interaction partner?

In order to investigate these questions, I conducted a *dyadic drumming study* in which female individuals of four different age groups (age range: 5–80 years) were instructed to drum in synchrony with each other in same- and mixed-age dyads. A newly developed *dyadic drumming paradigm* was applied that allowed the investigation of developmental differences in goal-directed interpersonal action synchronization while minimizing the complexity of the synchronization process.

The following three sections are organized in accordance with the research questions. Within each section, I will first summarize the main results and subsequently interpret them in line with existing theoretical background and empirical evidence. In the fourth section, I will highlight strengths and limitations of the present study before drawing a general conclusion on the present investigation. Finally, I will provide directions for future research on interpersonal action synchronization.

#### 4.1 Individual Antecedents of Interpersonal Action Synchronization

In the theory part, I introduced a theoretical model of the lifespan development of goal-directed interpersonal action synchronization. I proposed that the ability to synchronize one's actions with those of others develops in close interrelation to competencies pertaining to *life mechanics* and *life pragmatics* that change with age. To be able to synchronize one's actions with those of others, individuals need to perceive their own and others' actions (*sensory system*), predict them (e.g., based on *social experience*), and continuously react to them (*motor system*). That is why I hypothesized that individuals' higher sensorimotor abilities and social competencies would predict higher dyadic action synchronization accuracy within a dyad.<sup>30</sup> To investigate this question, individuals' sensorimotor abilities (i.e., individuals' synchronization accuracy when drumming with a metronome) and individuals' social competencies (i.e., interpersonal flexibility, situational flexibility, and social skills) were regarded as indicators of life mechanics and life pragmatics, respectively.

Beyond expected individual differences in the two functional components of life mechanics and life pragmatics, the main focus of my interest was on age-related differences in these underlying individual characteristics. In line with empirical evidence on developmental change in sensorimotor abilities and social competencies (e.g., Astington et al., 1988; Dempster, 1992; Drewing et al., 2006; Li et al., 2004; Silbereisen & Ahnert, 2002; Slessor et al., 2007), I expected age-group differences in the four individual predictors of interest.

To investigate individuals' synchronization abilities with a mechanical time keeper in the present study, each participant drummed in synchrony with different metronome frequencies in single conditions. Individual synchronization tasks (previously implemented as tapping paradigms) are described as a good means to investigate individuals' synchronization abilities (for overview, see Aschersleben, 1994; Drewing et al., 2006; Repp, 2005). The outcome of this synchronization process, that is, *individual asynchrony*, was used as an indicator of individuals' sensorimotor abilities. At a descriptive level, younger adults' individual synchronization accuracy when drumming with a metronome appeared most accurate (i.e., they showed the lowest individual asynchrony as compared to all other age groups), whereas younger children performed least accurately. Furthermore, older children and older adults showed higher individual asynchrony than younger adults, but lower asynchrony than younger children. These descriptive results on age-group differences in individual synchronization accuracy resemble the proposed U-

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<sup>30</sup> The terms, *interpersonal* and *dyadic* action synchronization will be used exchangeably in the following.

shaped trajectory of individuals' synchronization abilities across the lifespan (e.g., Drake et al., 2000; Drewing et al., 2006; Krampe et al., 2002). However, the described differences in individual asynchrony were not significant between all age groups: Younger children showed significantly higher individual asynchrony than all other age groups and older children performed less accurately than younger adults. Differences in the ability to synchronize with a mechanical time keeper, however, did not reach significance between younger and older adults. The simplicity of the task, that is, synchronized drumming to non-rhythmic metronome frequencies, may explain why, in contrast to previous research using more complex synchronization tasks (e.g., Krampe et al., 2002), younger adults did not outperform older adults in the present study.

In line with the literature, I also expected age-group differences in the predictors of social competencies: As indicators of life pragmatics these have been described to develop in the first years of life and to remain relatively stable until older adulthood as compared to indicators of life mechanics. In the present study, although younger children appeared to be rated as being least competent in adjusting to individuals of different ages in various situations (i.e., *interpersonal flexibility*) compared to all other age groups, the effect of age-group differences did not reach statistical significance. These findings do not correspond to the developmental trajectories proposed for social competencies to remain relatively stable or even increase in older adulthood (e.g., Astington et al., 1988; Happé et al., 1998; Silbereisen & Ahnert, 2002). It might be that others who reported on participants' interpersonal flexibility implicitly calibrated their evaluation only to the age of the target person (i.e., comparison to same-age individuals), effectively reducing the possibility to find a lifespan trend. This non-significant result can also be due to the small size of the present sample (i.e., 18 participants per age group) resulting in low statistical power for group-level analyses.

However, in accordance with results from previous research, younger children were rated as having significantly less *social skills* (i.e., children's competence, assertion, and self-control when acting alone or interacting with others) than older children.<sup>31</sup> Furthermore, self-reports indicated higher *situational flexibility* in older than in younger adults, that is, older adults rated their capability to show different behaviors across various situations more highly than younger adults.<sup>32</sup> Age-group differences in social skills and situational flexibility are in line with the assumption that social competencies develop early in life and remain relatively stable or even increase until older adulthood.

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<sup>31</sup> Adults were not rated on social skills.

<sup>32</sup> No self-report on situational flexibility was available for children.

To conclude, results indicate that younger children possess the lowest sensorimotor abilities (as indicators of *life mechanics*) as compared to all other age groups, whereas there were no differences between younger and older adults. Age-group differences in social competencies (as indicators of *life pragmatics*) were only partially consistent with the expected developmental trajectories: On the one hand, there appeared to be no significant age-group differences in others' report on interpersonal flexibility. On the other hand, in line with previous research, older adults' self-reported flexibility as a predictor of individuals' social competencies was even higher than younger adults', and older children were rated as having more social skills than younger children. Although some of the expected age-group differences in indicators of life mechanics and life pragmatics did not reach the level of statistical significance, to a large extent, findings overall resemble the expected underlying lifespan developmental trajectories for life mechanics and life pragmatics (e.g., Schindler & Staudinger, 2005; Staudinger & Pasupathi, 2000).

By means of multilevel analyses that accounted for the specific hierarchical and dependent data structure, I analyzed the relationship of these individual sensorimotor abilities and social competencies to interpersonal synchronization accuracy. Based on the respective results, the following two sections will discuss how differences in the individual predictors of sensorimotor abilities and social competencies (i.e., individual asynchrony, interpersonal flexibility, situational flexibility, and social skills) relate to interpersonal action synchronization accuracy. In an excursus, I will also address first evidence suggesting that age-related stereotypic expectations may influence interpersonal action synchronization accuracy.

#### 4.1.1 Sensorimotor Abilities

In the first hypothesis, I expected a positive relationship between individual sensorimotor abilities and interpersonal action synchronization accuracy. In line with the hypothesis, the more accurately participants performed in drumming in synchrony with a metronome (as indicator of individuals' sensorimotor abilities), the better they were able to synchronize with another person in the dyadic context.

Individuals' perceptual and motor abilities have been described as underlying the ability to synchronize with external stimuli, such as a mechanical (i.e., metronome) or a human time keeper (i.e., person). Similar, if not identical, mechanisms are assumed to account for both individual and interpersonal action synchronization (e.g., Knoblich & Sebanz, 2006; Tsai et al., 2006). In the present study, *dyadic asynchrony*, that is, the mean synchronization accuracy between two participants within a session, was used to operationalize interpersonal action synchronization

accuracy. Results supported the hypothesis: The present research suggests that individuals who showed higher synchronization accuracy when drumming with a metronome, also drummed more synchronously when paired with another person. This indicates that individuals' general synchronization abilities (based on perceptual and motor skills) are related to their ability to synchronize their own actions with others'. When synchronizing with a mechanical or a human time keeper, it is necessary to perceive the temporal properties of the external event (e.g., metronome click, partner's drumbeat) and to produce correct motor reactions in time (for overview, see Aschersleben, 1994; Drewing et al., 2006; Summers, 2002). Individuals who possess timing-related abilities (i.e., time perception and production) can make use of them in individual as well as interpersonal situations and therefore show high synchronization accuracy in both contexts.

#### 4.1.2 Social Competencies

In line with the literature, I expected that, beyond sensorimotor abilities, social competencies would also be relevant for successful interpersonal action synchronization (e.g., Schmidt et al., 1994; Tsai et al., 2006). Therefore, different indicators of social competencies were analyzed as predictors of interpersonal action synchronization accuracy, namely, *interpersonal flexibility*, *situational flexibility*, and *social skills*. The respective results will be discussed successively in the next sections.

*Interpersonal flexibility.* I hypothesized that the ability to adjust to individuals of different ages in different situations would affect interpersonal action synchronization accuracy. In contrast, I only found a marginal effect of interpersonal flexibility that could not be interpreted with confidence and that even vanished when simultaneously controlling for the sensorimotor predictor (i.e., individual asynchrony). Although individuals who are interpersonally flexible have been reported as being competent in terms of the efficiency to adapt their interaction strategies and to adjust towards the behavior of various others (e.g., Martin & Rubin, 1995), the predicted positive effect on interpersonal action synchronization accuracy was not supported by the present study.

There are several probable reasons for this finding: First, interpersonal flexibility did not differ between the age groups. Presumably, others implicitly adjusted their report on participants' interpersonal flexibility only towards the age group of the target person. This led to lacking age variance in this measure of social competencies and therefore did not capture age-related differences in individuals' abilities to synchronize with others. A second reason is related to the

applied experimental paradigm: One of the main criteria of the dyadic drumming paradigm was the minimization of the complexity of the synchronization task. This was advantageous for the controlled investigation of interpersonal action synchronization, but may have led to a loss of social exchange processes occurring in natural interactions. As participants were only introduced to each other briefly at the beginning of a session and thereafter could only hear each others' drum beats, the social aspects of the interaction process were strongly reduced. Therefore, sensorimotor abilities were presumably of higher relevance for the dyadic outcome as operationalized in the present study than social competencies. Third, individuals' abilities to synchronize with a metronome were assessed more directly (by the drumming paradigm) than interpersonal flexibility (by others' report questionnaires). In his lens model, Brunswik (1956) distinguished between *proximal* and *distal* environmental factors. While a proximal variable is directly accessible, distal variables are not directly observable and require further interpretation. In the present context, individual asynchrony can be described as a proximal variable because it is directly measurable for each individual. In contrast, other individuals who report on interpersonal flexibility only have indirect access to the variable of interest, that is, they need to evaluate and interpret different situations. It is therefore likely that within an interpersonal context, significant others have a different, more distal view that is less precise in evaluating individuals' interpersonal synchronization behavior than experimental measures of individual synchronization abilities. Furthermore, individual and interpersonal action synchronization accuracies were measured very similarly: In both situations, individuals were asked to drum in synchrony with a drum sound that they perceived through their head phones. It is obvious that the similarity between the two tasks (i.e., individual and dyadic) enhances the statistical relationship between them. Finally, the non-interpretability of the result may also be related to a lack of statistical power: Due to the model fit criterion (DIC), the marginal relationship between interpersonal flexibility and dyadic asynchrony could not be interpreted with confidence. Particularly as there is no empiric evidence on the sensitivity of the DIC to detect small effects in small-sized samples, further research is needed with larger samples. So far, interpersonal flexibility has also mainly been assessed through questionnaires (self- and others' report; e.g., Martin & Rubin, 1995; Paulhus & Martin, 1988). Findings from the present study suggest the application of more direct measures of interpersonal flexibility in social situations, for example, using observation methods in different situations with varying interaction partners (see below).

*Situational flexibility and social skills.* Two additional social competencies were hypothesized as being relevant in interpersonal action synchronization processes, namely, *situational flexibility* (i.e., the ability to perform different behaviors appropriately across varying situations) and basic

*social skills*. That is why I expected that higher individuals' situational flexibility and better social skills would be related to higher accuracy in interpersonal action synchronization.

Contrary to my hypothesis, situational flexibility, which was measured as the self-reported capability to perform a specific behavior required in different situations, was not associated to differences in interpersonal action synchronization accuracy for dyads among adults. There are two possible explanations for this finding. First, theoretically, the construct is closely related to interpersonal flexibility. Although it differs in the reference context of the questions (interpersonal vs. individual) and in the operationalization (self- vs. others' report), in comparison to the sensorimotor predictor, it is also a rather indirect measure of individuals' possible behavior. As pointed out in the context of the non-interpretable effect of interpersonal flexibility (see above), another reason may be the minimization of complexity of the interpersonal synchronization situation, which presumably led to less natural social exchange processes. In this case, social competencies may be less important for the dyadic synchronization outcome than in naturally occurring synchronization processes. Finally, the rather small sample size (36 participants) underlying the respective analyses may be another reason for the non-reliable result due to lack of statistical power.

*Social skills* (i.e., the competence, assertion, and self-control when acting alone or interacting with others) were assessed as reported by kindergarten nurses or teachers on a standardized rating scale for children only (SSRS; Gresham & Elliott, 2000). Results indicated that the higher children were rated on social skills, the more accurate their interpersonal action synchronization performance was. Social skills thus appear to be important antecedents of interpersonal action synchronization. *Perspective taking*, as one basic component of social skills, includes the perception of attributes of the other person as well as of the interpersonal dynamics. Being able to take into account the perspective of the interaction partner enhances prediction of future events and leads to more coordinated goal-directed interaction processes. For example, individuals higher in perspective taking have been reported to show higher non-intentional interpersonal synchronization than individuals with lower scores on perspective-taking skills (e.g., Chartrand & Bargh, 1999). Various aspects of social skills, for example, how individuals make sense of themselves and others' psychological processes (e.g., thoughts, emotions, intentions) as well as different adaptivity processes in adulthood are reported to accumulate and change across the lifespan (e.g., Petermann et al., 2004; Silbereisen & Ahnert, 2002; Staudinger & Pasupathi, 2000) and were assumed to be important for interpersonal action synchronization. Results from the present study are in line with previous findings and support theoretical assumptions, at least for children: If children are able to apply their knowledge about themselves and others and

respective regulatory functions and behaviors to the interpersonal situation, they are more likely to perform accurately when synchronizing with others.

To conclude, although the effect of social competencies was not supported for all age groups, there was some first evidence that dyads including individuals with higher social competencies reach higher interpersonal action synchronization accuracy than other dyads: Social skills were positively related to dyadic action synchronization accuracy in children. The marginal effect of interpersonal flexibility for all age groups, which, however, could not be interpreted with confidence, did also hint in the hypothesized direction. However, interpersonal flexibility showed no effect over and above individuals' sensorimotor abilities (i.e., the effect vanished after controlling for individual asynchrony). This can be explained, for example, by the low relevance of social competencies within the very controlled dyadic drumming situation and differences in the directness of assessment between sensorimotor (i.e., directly measured) and social predictors (i.e., self- and others' report). These results claim further research explicitly on the role of age-related differences in social competencies for interpersonal action synchronization.

Theoretical assumptions and findings on age-related differences in some of the respective predictors, led to a follow-up question: Are different abilities (i.e., sensorimotor vs. social) of higher relevance for different age groups? For example, one could further hypothesize that older adults compensate a functional loss associated with the *mechanical* component by activating experience-based or *pragmatic* competencies. The effect of social competencies on interpersonal action synchronization accuracy may therefore be more pronounced in the older adult age group. Unfortunately, due to the small sample size, the interactions between age group and nature of ability could not be directly analyzed in the present investigation. Therefore, this question should be addressed further in future research. I partly approached the question of an interaction between age and individual levels of functioning by analyzing differences in dyadic synchronization accuracy between the age-group compositions of the dyads as further associated with individual predictors. With these analyses it was possible to test whether beyond differences in the dyadic age-group combinations, sensorimotor abilities and social competencies are related to variability in dyadic asynchrony. The respective results will be discussed below.

#### 4.1.3 Excursus: Are Age-Specific Stereotypes Related to Interpersonal Action Synchronization?

Using an exploratory approach, I also aimed at examining the relationship between positive and negative age-specific stereotypic expectations and interpersonal action



synchronization accuracy. In the present study, individuals were asked to rate their positive and negative expectations towards all four age groups of interest. For the analyses underlying the respective results, I used a mean composite of reciprocal stereotypic expectations for each dyad (see also Section 3.4.3). Results indicated that after controlling for dyadic age-group combinations, the more positive the reciprocal stereotypic expectation towards the age group of the respective partner was, the higher the synchronization accuracy in the dyad was. In other words, dyads in which individuals had more positive age-related stereotypic expectations towards each other showed higher interpersonal action synchronization accuracy than dyads with more negative expectations.

What are the possible mechanisms underlying this effect? In general, interaction processes have been reported to be affected by the activation of concepts (e.g., stereotypes, age-specific attitudes) that simultaneously activate respective motor codes (e.g., Bargh et al., 1996; Ferguson & Bargh, 2004; Hommel et al., 2001; Marsh et al., 2006). I therefore proposed that the integration of expectations towards the behavior of the interaction partner is necessary for successful interactions (e.g., interpersonal action synchronization). Expectations that match the partner's actual actions facilitate the prediction of future events, which in turn enhances interpersonal processes. This also includes expectations that are based on stereotypes, for example, with respect to the age group of the respective partner. However, it may be possible that the partner's actions are not in line with these expectations. In this case, additional processes are necessary to adjust the former expectations to the real action. For example, *perspective-taking* abilities help to reduce stereotype-driven behavior (e.g., Galinsky & Moscovitz, 2000).

In the present study, however, it was only possible to distinguish between positive and negative stereotypic expectations with regard to the age group of the respective partner. It was therefore not examined (a) whether individuals' expectations matched the actual behavior of the partner or (b) whether the interaction partners acted according to their own general age-related expectations.<sup>33</sup> Nonetheless, the finding that, regardless of dyadic age composition, positive stereotypic expectations towards the age group of the partner were positively related to interpersonal action synchronization accuracy was in line with previous research indicating that positive or negative age stereotypes are related to communication outcomes, at least between younger and older adults. For example, Chen and King (2002) reported that individuals with a positive stereotype towards the other age group perceived a higher level of intergenerational

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<sup>33</sup> For example, future studies could separate the partners from each other and experimentally alter the age group of the assigned partner or manipulate his or her performance to be congruent or incongruent with the general respective age-related stereotype. This could help to disentangle the effects of individuals' performance and stereotypic expectations.

communication satisfaction than those with neutral or negative stereotypes. To my knowledge, this effect has mostly been investigated in the context of age-related stereotypes towards older adults that are on average more negative than towards younger adults (e.g., Hummert, 1990; Kite, Stockdale, Whitley, & Johnson, 2005). For example, several studies have shown that negative stereotypes towards older adults induce behavioral differences, such as, over-accomodation or patronizing (e.g., M. M. Baltes & Wahl, 1996; Bargh et al., 1996; Coupland et al., 1988; Kemper & Harden, 1999; Thimm, Rademacher, & Kruse, 1998). The present study therefore adds a valuable amendment as it also included the assessment of age-related stereotypic expectations towards children. The finding that after controlling for the age group of the partner a more positive stereotypic expectation was related to higher interpersonal action synchronization accuracy, hints that stereotypic attitudes towards children, which could be more positive than towards older adults, may also be related to achieving attunement during interaction processes. As the empirical evidence from the present study is not clear in this regard, that is, children were not rated more positively than adults by all age groups, future research is necessary to investigate how *positive* age-related stereotypical expectations in particular gain importance when interacting with children.

To conclude, the effect of positive stereotypic expectations towards the age group of the interaction partner on the dyadic outcome (irrespective of the age of the partner) can be interpreted in line with findings on the general effect of stereotypes in different domains (e.g., age, socio-economic status, race-related) on individual and interpersonal behavior (e.g., Bargh et al., 1996; Chen & Bargh, 1997; Darley & Gross, 1983; Rothermund, 2005). A very interesting follow-up finding was that in contrast to stereotypic expectations the reciprocal *first impressions* between the interaction partners did not show any effect on dyadic action synchronization accuracy. Furthermore, age-related stereotypic expectations were not related to the first impression of the interaction partner. This supports the assumption that the anticipation of the other person's behavior may be more based on the activation of already established stereotypes than on interpersonal perception at the beginning of a session (i.e., first impression), especially in a very artificial and controlled interaction setting.

#### 4.1.4 Summary and Conclusions

To conclude, in line with the first hypothesis, individuals who showed better sensorimotor abilities (i.e., lower asynchrony when synchronizing with metronome-like drum beats) also achieved higher interpersonal action synchronization accuracy. Results for social competencies were less clear in the present study: Although there was some evidence that dyads including children with higher social skills reached more accurate interpersonal action

synchronization than dyads consisting of children with lower social skills, the expected association between flexibility and higher interpersonal action synchronization was not consistently supported. Explanations for this could be (a) the lack of age variance in others' report on interpersonal flexibility, (b) the low relevance of social competencies in solving the dyadic drumming task, or (c) differences in the measurement of the individual predictors (measured directly vs. others' report questionnaires). However, the effect of social skills for children could indicate that social functioning is related to interpersonal synchronization at least in children. Future studies applying more complex interaction tasks or using more direct measures of social competencies are necessary to further investigate the role of social competencies that were theoretically considered relevant for interpersonal action synchronization.

Furthermore, there was first evidence suggesting that dyads holding more positive reciprocal stereotypic expectations about the partner's age group reach higher interpersonal synchronization accuracy than those with more negative reciprocal expectations (irrespective of dyadic age compositions). This finding is in line with previous research describing the relevance of stereotypes on individual and interpersonal behaviors.

#### **4.2 Developmental Perspective on Interpersonal Action Synchronization: Effects of Dyadic Age Compositions**

How does the ability to synchronize with others develop across the lifespan? This question was approached by analyzing how dyads of varying age compositions differed in terms of dyadic asynchrony. Each member of the four age groups (i.e., younger and older children, younger and older adults) was experimentally paired with one same-age partner and one partner from each of the three other age groups. This led to a total of ten different same- and mixed-age dyad combinations. I expected that due to age-related differences in individual abilities, interpersonal action synchronization accuracy would differ by dyadic composition. In the following section, I will first discuss how interpersonal action synchronization accuracy varied by dyadic age-group composition. Second, I will show how these dyadic differences in interpersonal action synchronization accuracy were related to individual predictors (i.e., sensorimotor abilities and social competencies).

#### 4.2.1 Do Dyads with Younger Adults Show Higher Interpersonal Action Synchronization Accuracy than Other Dyads?

Empirical findings from previous research suggested that younger adults show the highest functioning in indicators of both life mechanics and life pragmatics (e.g., P. B. Baltes et al., 2006; Lindenberger & Baltes, 1997). More specifically, individuals' sensorimotor abilities and social competencies that are crucial for interpersonal action synchronization were expected to show peaks of functioning in younger adulthood (e.g., Drewing et al., 2006; Krampe et al., 2001, 2002; Pouthas et al., 1998; Silbereisen & Ahnert, 2002; Slessor et al., 2007). I therefore hypothesized that younger adults would show the highest accuracy when synchronizing with a partner of their own age group. The results from the present study suggest a more differentiated picture: I found that same-age dyads with younger adults showed higher synchronization accuracy than most other dyads, except those only including adults (i.e., "younger adult - older adult," "older adult - older adult"). That is, younger and older adults surprisingly did not differ in their dyadic asynchrony when drumming with each other.

Findings from previous research also suggested that younger adults show highest functioning with regard to individual action synchronization abilities (e.g., Drake et al., 2000; Drewing et al., 2006; Krampe et al., 2002). At the same time, they appear to have the necessary experience-based social skills to represent and anticipate the partner's reaction (e.g., Happé et al., 1998; Silbereisen & Ahnert, 2002). As I proposed that individual sensorimotor abilities and social competencies belong to the main antecedents of the development of interpersonal action synchronization, I expected that younger adults, due to their high functioning in both, would also show the best performance in the interpersonal synchronization context. This high functioning could explain why, in comparison to dyads including children and older adults, same-age dyads of younger adults show higher interpersonal action synchronization accuracy.

However, a very interesting finding was that younger and older adults showed comparable levels of interpersonal action synchronization accuracy. In spite of the reported importance of sensorimotor abilities for interpersonal action synchronization, the applied paradigm seems to have created a context in which the ability to synchronize with others is maintained until older adulthood. In natural interactions, shared goals need to be detected and implicitly or explicitly committed to between individuals (e.g., Bratman, 1992; Gilbert, 1996; Searle, 1990). Furthermore, individuals must implement synchronized behavior as a means to reach the shared goal. In contrast, in the drumming paradigm the shared goal and the way to reach the goal were specified. This strongly facilitated the synchronization process, as the number

of optional action alternatives was reduced. Furthermore, this finding could partly be explained by the simplicity of the drumming task which, in contrast to previous studies (e.g., Drewing et al., 2006; Krampe et al., 2002), also resulted in older adults synchronizing with different metronome frequencies as accurately as younger adults. Also in line with this finding is that older adults showed similar levels of interpersonal flexibility as a predictor of social competencies as compared to younger adults. The non-reliable differences between adult dyads reflect the similarity in the predictors suggested to be relevant for interpersonal action synchronization.

The second hypothesis in this context was that younger adults, due to their high sensorimotor and social functioning, are best able to compensate for the possible lack of younger and older interaction partners' competencies. Therefore, I expected interpersonal action synchronization between one younger adult and partners of all other age groups to be more accurate than dyads without a younger adult. Results indicated that although younger adults showed high functioning in their individual abilities,<sup>34</sup> they were not able to fully compensate for the lack of children's interpersonal synchronization abilities, especially when they were paired with younger children. For example, younger adults synchronizing with younger children did not outperform older children synchronizing with older children or with older adults. Presumably, younger children produce a very chaotic and non-predictable drumming pattern, which makes it difficult, even for adults, to synchronize with them. However, in the mean-level approach of the present dissertation, it was not possible to judge whether younger children's performance was most variable within a dyadic situation compared to individuals from other age groups. Individuals' baseline variability when drumming at a tempo they felt most comfortable with did not account for differences in the dyadic performance (although younger children showed higher variability than adults). However, variability in the dyadic synchronization task can be different. To be able to further understand the underlying dynamical process within the interaction, it is necessary to analyze the data on a micro-level (see below).

In summary, same-age dyads with younger adults showed higher interpersonal action synchronization accuracy than most other dyadic age compositions, except pairings among adults. That is, this study provided a context where older adults maintained similar levels of performance as younger adults. This result also agrees with the finding that younger and older adults did not differ in individual antecedents of interpersonal action synchronization, namely, individual asynchrony and interpersonal flexibility. I assume that the application of the drumming paradigm provided a supportive setting, especially for older adults to synchronize with others: In contrast to naturally occurring interactions, the goal and the means to reach it were specified.

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<sup>34</sup> Their competencies (individual asynchrony and interpersonal flexibility), however, were similar to older adults'.

Complementary investigations of interpersonal action synchronization in more natural interaction processes could help to identify possible differences between younger and older adults' abilities to synchronize their actions with others.

In contrast to my second hypothesis, younger adults could not completely balance out all possible limitations in interpersonal synchronization abilities of their partners (e.g., higher variability in performance). That is, mixed-age dyads with one younger adult did not show higher synchronization accuracy than all other dyads without younger adults. Especially in pairings with younger children, younger adults could not compensate for their partners' lower interpersonal synchronization abilities.

#### 4.2.2 The Adults' Role in Interpersonal Action Synchronization: A Zone of Proximal Development for Children

A very interesting follow-up finding was that children of both age groups performed more accurately when paired with an older partner than in same-age dyads. This result can be interpreted in line with the concept of the *zone of proximal development* first introduced by Vygotsky (1933; cf. van der Veer & Valsiner, 1991). The zone of proximal development of a child is defined as the distance between the actual development, examined through independently solved tasks, and the level of the *potential* development of the child, examined through tasks solved by the child under the assistance of, or in cooperation with, more experienced partners (e.g., older interaction partners; e.g., van der Veer & Valsiner, 1991). Vygotsky argued that what children can do with the assistance of others is even more indicative of their developmental status than what they can do alone (e.g., Brown, Metz, & Campione, 1996). In the context of interpersonal action synchronization, I suggest that children benefit from the competencies of their older interaction partners with respect to their ability to synchronize their actions with others: Children's performance level is higher when synchronizing with an older partner than when synchronizing with a same-age partner.

Indeed, both younger and older children benefit from drumming with adults rather than their age peers. One important question is what aspects in adults' behavior facilitate interpersonal synchronization? There are two possible explanations: As has already been pointed out when introducing the theoretical background for this dissertation, adults (especially younger adults) were expected to show the most *flexible* behavior across different (social) situations. In interaction processes in general, the ability to flexibly adjust one's own behavior to the varying demands of the respective situation and the interaction partner has been suggested as a crucial antecedent for

successful interaction outcomes (e.g., Martin & Rubin, 1995). The original assumption therefore was that younger adults' highest flexibility also enables them to synchronize with interaction partners of all different age groups. However, this effect did not reach significance for the measures used in the present study: Although younger adults were rated highest on their ability to flexibly adjust to different individuals across various situations by others, differences between the age groups did not reach the level of significance. It is possible that others' ratings of individuals' interpersonal flexibility did not differ between the age groups because others implicitly adjusted their evaluation only to the age group of the target participant which resulted in lacking age variance of the measure. This measure of flexibility therefore was not related to children's higher synchronization accuracy when paired with adults.

Hence, an alternative hypothesis could be that adults are more *stable* in their performance. Stability may be adaptable in situations in which individuals experience very variable performance of their interaction partner. For example, being a stable time keeper in an interpersonal synchronization process can facilitate the partner's anticipation of future actions and therefore increase the interaction outcome. As explained above, I used a mean-level approach on interpersonal action synchronization accuracy in the present dissertation. That is, the mean dyadic asynchrony between two individuals within a session was used as the operationalization of interpersonal action synchronization accuracy. Therefore, it was not possible to refer to individuals' stability or variability in their drumming pattern when synchronizing with another person.<sup>35</sup> I suggest that future research should include, for example, time-series analyses to further investigate the dynamics within the synchronization process on a micro-level (e.g., Ashenfelter et al., in press). This may allow the detection of age-specific patterns (stable or variable) in interpersonal synchronization processes.

To conclude, follow-up analyses provided evidence that children of both age groups benefited from drumming with participants of an older age group. These results may suggest age-related differences in individuals' underlying interpersonal synchronization patterns (e.g., children may be more variable than adults), which leads to differences in accuracy when individuals of various age groups are asked to synchronize with each other. Future research should therefore follow up on questions about the effect of stability or variability on individuals' drumming performance in the dyadic context.

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<sup>35</sup> As mentioned above, although there were differences between children's and adults' stability when drumming *individually* at a tempo they felt most comfortable with, this variable did not account for differences in the *dyadic* performance.

### 4.2.3 Individual Asynchrony Is Related to Age-Associated Variability in Interpersonal Action Synchronization Accuracy

A final hypothesis in the context of the second research question referred to the assumption that the described relationship of varying age compositions of the dyads and variability in interpersonal action synchronization accuracy would be mediated by differences in sensorimotor abilities and social competencies. In the present study, it was not possible to analyze the mediation hypothesis directly through multilevel mediation analyses (e.g., Krull & MacKinnon, 1999, 2001), because of the specific hierarchical structure of the data (i.e., dyadic asynchrony differed on the dyadic outcome level whereas individual predictors differed on the individual level; see also Section 2.4.3). To approach this hypothesis, I analyzed whether individual asynchrony and interpersonal flexibility were related to variability in dyadic asynchrony that was related to differences in dyadic age composition.

The hypothesis corresponded with previous theoretical considerations that individuals would show age-related differences in antecedents of interpersonal action synchronization. These considerations were already supported by results indicating some age-related differences in indicators of sensorimotor abilities and social competencies (not across all age groups) underlying the ability to synchronize one's own actions with those of others, and also by the finding that variability in dyadic asynchrony was related to differences between dyadic age compositions. Furthermore, findings of the present study suggested that beyond differences in dyadic synchronization accuracy between same- and mixed-age dyads, individuals' abilities (particularly individuals' synchronization accuracy with a metronome) were relevant for the interpersonal synchronization outcome. Again, it is important to note that interpersonal flexibility (as an instance of social competencies) was unrelated to differences in dyadic asynchrony and therefore also did not correspond to the synchronization accuracy of varying dyadic age compositions in the present study. Future research applying more direct measures of interpersonal flexibility and other social predictors in less artificial interpersonal synchronization tasks may find other evidence for differences in dyadic asynchrony related to varying age compositions of the dyads to be further associated with individual differences in this social predictor.

However, differences in individuals' abilities to synchronize with a metronome were important, but not exclusively relevant for interpersonal action synchronization accuracy: The fact that part of the differences between the dyadic age compositions in interpersonal action synchronization accuracy remained reliable over and above individual asynchrony and interpersonal flexibility, reflects that there was some source of variance that was not captured by the chosen indicators of individuals' abilities. This may suggest that some proportion of



variability in interpersonal action synchronization accuracy lies uniquely in the interaction between the two individuals (i.e., within a specific dyad). I propose that it is the dynamic between the two individuals that cannot be solely predicted by each individual's single performance. Measuring individuals' synchronization accuracy with a metronome or flexibility in individuals' behavior via self- or others' reports still places the focus on single persons' adjustment abilities. In the interpersonal context, however, an individual has to continuously adjust his or her own action to the partner's while producing actions that influence the partner's behavior in turn (e.g., Fogel, 1993; Nowak et al., 2005; Tognoli et al., 2007). This mutual dynamic occurs at a micro-level of the interaction process and is based on continuing reciprocal feedback loops. Therefore, it is not meaningful to assume that the interpersonal process can be fully captured on the basis of individual abilities.

#### 4.2.4 Summary and Conclusions

In the present study, results indicate that differences in the age composition of the dyads are related to interpersonal action synchronization accuracy. Younger adults in same-age dyads showed higher interpersonal synchronization accuracy than most other dyads, except when compared to other pairings among adults (i.e., "younger adult – older adult" and "older adult – older adult"). This represents adults' ability to synchronize their actions with those of others that can be associated with underlying individual sensorimotor abilities and social competencies. Matching with the finding that younger and older adults did not differ in their individual synchronization abilities was that they also did not show differences when synchronizing with each other. This indicates that the drumming paradigm provides a context in which younger and older adults show similar levels of performance. Future research should investigate less artificial and more complex synchronization situations to further identify differences between younger and older adults in interpersonal action synchronization abilities.

The present study provided initial yet strong evidence that children benefit from synchronizing with a partner of an older age group. Presumably, it is adults' high functioning in interpersonal synchronization abilities that can facilitate children's synchronization performance (e.g., Kessler & Staudinger, 2007). However, besides differences in individual sensorimotor abilities there is also evidence for an effect that is assumed to derive directly from the interpersonal dynamic between the two individuals and that could therefore not be captured by measuring individuals' abilities only.

### 4.3 Consequences of Interpersonal Action Synchronization

The third main research question of the present study focused on the effect of interpersonal action synchronization on individuals' subjective evaluation of the interaction partner and the situation. Previous research on interaction processes suggested that more accurate or fluent coordination leads to a more positive experience of the interaction and the interaction partner (e.g., Kulesza & Nowak, 2003; Tickle-Degnen & Rosenthal, 1987; van Baaren et al., 2003; Warner, 1992). Transferring these results on interpersonal action synchronization, I hypothesized that individuals in dyads reaching higher synchronization accuracy would evaluate their interaction partners and the social situation more positively.

Results obtained within the present dissertation supported this hypothesis. At the end of the respective session, participants in dyads with more accurate dyadic drumming performance evaluated their drumming partner more positively than those in dyads with lower synchronization accuracy. Furthermore, they experienced the entire situation more positively and as less difficult, and were more satisfied in situations when they drummed in good synchrony with their partner than in situations with a less accurate outcome. These results will be discussed in the following two sections.

#### 4.3.1 Interpersonal Action Synchronization Accuracy Affects Individuals' Experience of the Interaction Partner

Participants in the present study evaluated their drumming partner at the end of the session more positively (as more likeable, friendly, and cooperative) and wanted to get to know their drumming partner better (i.e., ratings on the *last impression* scale) when they reached higher interpersonal action synchronization. These results are in line with theoretical considerations that suggested that synchrony has a communicative function of its own: The level of synchrony during an interaction may indicate the degree of understanding, agreement, or support experienced between individuals (e.g., Lakin et al., 2003). Previous research already reported findings on the positive association between non-intentional and goal-directed interpersonal synchronization and the evaluation of the interaction partner. For example, several studies provided empirical evidence that non-intentional synchronization (e.g., mimicking during conversation processes) was associated with positive interpersonal evaluations (e.g., rapport; e.g., Bernieri et al., 1988; Lakin & Chartrand, 2003; van Baaren et al., 2003). With respect to goal-directed coordination, Kulesza and Nowak (2003) found that more accurate dyadic outcomes led to more positive evaluations of the actual partner than of partners who were perceived as

coordinating less in a dyadic coordination task. The feeling of being “in synch” with another person is experienced highly positively. As individuals interact, they generally strive for smooth and fluent interactions. Moreover, synchronized actions and temporal patterns have been proposed to facilitate the predictability of future events (e.g., Tickle-Degnen & Rosenthal, 1987; Warner, 2002). This is a crucial factor for successful interaction processes. The fact that the results from the present study, based on a very artificial experimental situation, are in accordance with previous research on naturally occurring interaction or synchronization processes, underlines the importance of interpersonal action synchronization outcomes for interpersonal evaluation.

Furthermore, the effect of dyadic synchronization accuracy on the evaluation of the drumming partner at the end of the session was not related to the age of the partner or to the interaction between the partners’ age and dyadic asynchrony in a specific session. This emphasizes the relevance of synchronization accuracy on the interpersonal experience that is independent of the partner’s age. Equivalent individual ratings of the drumming partner at the beginning of the session (i.e., *first impression*) showed a strong positive relation to last impression. This is in line with the literature that consistently reports an important long-lasting influence of first impression and primacy effects during social judgment processes (e.g., Asch, 1946; Anderson, 1965; Bierhoff, 1989; Gawronski et al., 2002). However, the findings of the present study indicate that the experience of interpersonal action synchronization accuracy additionally is highly related to the interpersonal evaluation process: First, dyadic synchronization accuracy that was reached between two individuals predicted the subjective evaluation of the drumming partner at the end of the session irrespective of how positively the partner had been evaluated at the beginning of the session. Second, an even more interesting finding was that both individuals in dyads reaching higher synchronization accuracy showed an *increase* in their respective positive subjective evaluation of the drumming partner from the beginning to the end of a session, whereas individuals in dyads reaching lower synchronization accuracy showed a decrease in their evaluation. These findings indicate that the experience of synchronization during the interaction is also related to a *change* in the evaluation process with regard to the interaction partner. That is, besides replicating results from previous research indicating that interpersonal action synchronization accuracy is closely related to the interpersonal experience at the end of an interaction, the present study adds novel insight on possible dynamical aspects of interpersonal impression building during social interaction processes.

### 4.3.2 Interpersonal Action Synchronization Accuracy Affects Individuals' Experience of the Situation

In close analogy to the findings described above, individuals in dyads who drummed in a more synchronized way evaluated the situation more *positively*, as less *difficult*, and reported being more *satisfied* than individuals in dyads that reached higher dyadic asynchrony. That is, the experience of a successful and smooth interaction leads to a more positive experience of the whole social situation. As described above, temporal or rhythmic patterns may enhance interaction processes because they facilitate the anticipation of the beginning and termination of future events (e.g., Bernieri & Rosenthal, 1991). This explains why situations in which higher synchronization accuracy was reached were experienced as less difficult. It has been proposed that there is an intrinsic tendency in individuals to move towards being “in synch” with others (Nowak et al., 2005; Vallacher et al., 2005). Interactions in which individuals are not able to coordinate their actions in time (e.g., novice dancers) are often experienced as strenuous and unsatisfactory. In contrast, social situations that are characterized by interpersonal action synchronization are experienced as satisfying (e.g., Kulesza & Nowak, 2003). Evidence from the present study support these propositions.

### 4.3.3 Summary and Conclusions

Interpersonal action synchronization can be understood as a crucial factor that affects interpersonal perception with respect to self- and other attributions. In my view, the most interesting aspect of the present findings is that even though individual social predictors did not show unique effects on dyadic synchronization, dyadic performance obviously is strongly related to the social experience. This implies that interpersonal action synchronization plays a crucial role for subjective social-interaction outcomes (see also Bernieri & Rosenthal, 1991; Harrist & Waugh, 2002; Kulesza & Nowak, 2003; Warner, 1992). As already mentioned above, a potential reason why social competencies did not show highly interpretable effects on dyadic asynchrony in the present study could be the artificiality of the applied paradigm. The dyadic drumming task as such may therefore not require many social competencies. However, the accuracy of interpersonal action synchronization throughout the interaction situation, in turn, is strongly related to the interpersonal experience. This is consistent with the idea of enhancing and facilitative effects of temporal patterns for social interaction processes in general. Synchronized actions allow better prediction of future events during the interaction and therefore facilitate interpersonal processes (Tickle-Degnen & Rosenthal, 1987; Warner, 2002). Successful (i.e., synchronized) interactions are associated with positive experiences and lead to a more

positive evaluation of the interaction partner and the situation, even in a very controlled experimental setting.

#### 4.4 Strengths and Limitations of the Present Dissertation

In the following sections, I will first summarize the main strengths of the present study (e.g., application of a *lifespan-developmental* perspective, development of the *dyadic drumming paradigm*) and then point out some possible limitations (e.g., regarding limited *generalizability*).

##### 4.4.1 Strengths

*Lifespan-developmental perspectives.* As pointed out in the theoretical background of this dissertation, interpersonal synchronization has been described to occur non-intentionally very early in development (e.g., Condon & Sander, 1974a, 1974b) and to be responsible for various successful interaction processes across the lifespan (e.g., Bernieri, 1988; van Baaren et al., 2004; Warner, 1992). Furthermore, the ability to synchronize with others has been proposed as having a crucial developmental function (e.g., social and cognitive development; Harrist & Waugh, 2002). So far, there has only been sparse empirical evidence on the development of *individuals'* goal-directed synchronization abilities in general (e.g., Drake et al., 2000; Drewing et al., 2006; Krampe et al., 2002) and none when it comes to questions about the development of the ability to synchronize *with other individuals* to reach a shared goal.

From a theoretical perspective, the present investigation is a unique contribution to the literature because the theoretical framework is closely derived from the key considerations of lifespan-developmental theory (e.g., P. B. Baltes, 1987, P. B. Baltes et al., 2006). Investigating individuals' competencies that pertain to life mechanics and life pragmatics as being relevant for the development of goal-directed interpersonal action synchronization is a vital novelty and can help to further understand how individuals develop the ability to synchronize their actions with others. In the same context, a methodological strength of the present cross-sectional investigation was the inclusion of individuals from a wide age range (i.e., younger and older children, younger and older adults). Investigating same- and mixed-age dyads made it possible to examine age-related differences in interpersonal action synchronization, including developmental aspects underlying individuals' abilities to synchronize with others as well as inter-generational action synchronization processes. Especially, questions with regard to facilitation effects in mixed-age dyads (e.g., do children benefit from adults' functioning?) could be addressed (e.g., Kessler & Staudinger, 2007).

*Dyadic Drumming Paradigm.* Another important strength of the present study is the development of the dyadic drumming paradigm. So far, there has been no standardized research paradigm to investigate developmental aspects in goal-directed interpersonal synchronization processes. The origin of the dyadic drumming paradigm was based on the long history of studies that implemented different versions of tapping paradigms (for overview, see Aschersleben, 1994, 2002; Repp, 2005). Most studies aimed at investigating *individuals'* ability to synchronize with mechanical time keepers. Therefore, profound theoretical considerations and valuable previous empirical evidence from tapping studies was available. The tapping paradigm was extended to the dyadic context such that two individuals were instructed to synchronize with each other at a stable tempo they prefer. Instead of tapping, individuals' task was to *drum* in synchrony to allow the control of possible age-related differences in fine motor skills (e.g., Holle, 1988; Salthouse, 1982; Shumway-Cook & Woollacott, 2001). As has already been emphasized in earlier sections, the dyadic drumming paradigm has four major advantages: First, just like tapping paradigms, the complexity of the synchronization process is minimized to control for factors that influence natural synchronization processes and focuses on the temporal coupling between two movement sequences (e.g., Drewing et al., 2006). Second, because a shared goal was explicitly assigned to the two individuals by instruction (i.e., to synchronize with each other), it was possible to investigate *goal-directed* interpersonal action synchronization directly. Third, although the paradigm assesses synchronization in a very controlled setting, it is still feasible to measure the adjustment process between two individuals who strive to synchronize with each other. Fourth, the paradigm can be applied to various age groups (children as well as adults) because it controls for possible age-related differences in fine motor skills. To summarize, the dyadic drumming paradigm is a very valuable achievement: It is a highly flexible tool that can facilitate future research on different aspects of goal-directed interpersonal action synchronization.

*Systemic approach.* Another point to highlight is the systemic approach of the present investigation. Previous studies on interpersonal action synchronization always included an external mechanical stimulus with which two or more participants were instructed to synchronize (e.g., Helmuth & Ivry, 1996; Oullier et al., 2003). Therefore it was not possible to examine interpersonal action synchronization as an adjustment process between two dynamic time keepers, that is, between two individuals. Furthermore, Fogel (1993) claimed that most operationalizations of synchrony often assumed unilateral anticipation and adjustment of one partner to the other (e.g., parent-child interactions), and thereby ignored the "systemic wholeness" and dynamic nature of the interaction. Studying goal-directed interpersonal action synchronization with the dyadic drumming paradigm in the present study made it possible to

refer to synchrony not as an all-or-none condition but to think of two or more individuals approaching synchrony or moving away from synchrony. Using the dyadic drumming paradigm thus allowed integration of both a dynamic and a systemic perspective.

#### 4.4.2 Limitations

*Generalization.* One of the biggest strengths of the present investigation, namely, the use of the dyadic drumming paradigm, can also be seen as one of its limiting factors. The advantage of investigating interpersonal action synchronization in a very controlled setting minimizes possible influencing factors that occur in natural interactions (e.g., Aschersleben, 2002; Drewing et al., 2006), but limits possible generalizations to other interaction processes at the same time. For example, the dyadic drumming paradigm assessed *in-phase* synchronization (as opposed to alternating action patterns) between two individuals. This has been described as the easiest form of synchronization to achieve and maintain (e.g., Vallacher, et al., 2005). Furthermore, synchronization of *discrete* actions (i.e., single drum beats) is a very basic form of interpersonal synchronization. Many natural interaction processes are much more complex and include, for example, synchronization of continuous actions (e.g., limb swinging; e.g., Nowak et al., 2005). In addition, participants only received *auditory* feedback of the other person's actions. This also differentiates from naturally occurring interactions in which it is possible to combine feedback from different channels. Moreover, synchronization usually does not only occur between two individuals; frequently more than two individuals are involved. Thus, investigating dyads as the smallest possible social unit does not allow reasoning about how other social units (i.e., triads, groups), synchronize with each other. All the described aspects make it difficult to generalize towards interpersonal action synchronization in general.

Beyond limitations that derive directly from the application of the dyadic drumming paradigm, there are two more general methodological limitations that reduce generalizability: First, the present cross-sectional investigation, which was based on four different age groups, only allows conclusions on age-related differences and can only hypothetically be transferred to other age groups. Furthermore, it did not investigate developmental change in the ability to synchronize one's actions with those of others directly. First evidence on age-group differences can therefore only function as an indicator of underlying developmental change. Further longitudinal research would be necessary to allow for conclusions on underlying developmental trajectories of the ability to synchronize goal-directedly with others and its underlying mechanisms. Second, mere inclusion of same-sex female dyads does not permit generalization towards mixed-sex dyads or male same-sex dyads. To account for previous empirical evidence of

gender-related differences in interaction processes (e.g., Rotondo & Boker, 2002; Schmid Mast, 2004), it must be further investigated whether implicit role allocations within other dyadic combinations lead to differences in interpersonal action synchronization.

In my view, the present study is a starting point to investigate interpersonal action synchronization in a very elaborate and controlled way. The dyadic drumming paradigm is a very flexible research tool with that many of the just described limitations can easily be addressed in future studies. For example, it is possible to investigate alternating synchronization processes (i.e., individuals taking turns when drumming), the effect of different feedback modes (e.g., individuals are allowed to see each other), or synchronization between more than two individuals of the same and opposite gender. However, before further applying the dyadic drumming paradigm to other groups (e.g., age groups, men and women), the *measurement equivalence* of the method should be validated. Due to the small sample size, it was not possible to test this in the present study. The question if the experimental paradigm measures the same construct for all age groups of interest should be investigated for future implementations of the dyadic drumming paradigm. Analyzing measurement invariance between the respective groups as well as over time could provide further insights into the external validity of the paradigm (e.g., Hertzog & Nesselrode, 2003; Horn & McArdle, 1992; Little, 1997; Meredith, 1993).

#### **4.5 Directions for Future Research on the Development of Interpersonal Action Synchronization**

In previous sections, I have already referred to different possibilities for future research to continue and improve the empirical investigation of the development of goal-directed interpersonal action synchronization. In the final sections, I will summarize these suggestions and conclude with three, more general, possible future research directions. In particular, I propose that research on the development of interpersonal action synchronization can benefit from (a) investigating the underlying dynamical structure, (b) including a behavioral operationalization of flexibility, and (c) examining neural correlates of interpersonal action synchronization processes.

##### **4.5.1 The Dynamic Process of Interpersonal Action Synchronization**

As pointed out in earlier sections, I interpret interpersonal action synchronization as an adjustment process between two or more individuals. During this process, individuals function as each others' time keepers (e.g., Haken et al., 1985; Schmidt et al., 2007; Wilson & Wilson, 2005;



see also Section 1.2.2). However, the aim of the present study was the investigation of the outcome of an interpersonal synchronization process, that is, the mean asynchrony between two individuals within a specific time frame. Future research is necessary to detect the dynamic process underlying interpersonal action synchronization. Therefore, *time-series analyses* have recently been implemented in interpersonal coordination research (e.g., Ashenfelter et al., in press). Identifying dynamical structures (e.g., *lead-lag*) within synchronization processes can help to understand the interpersonal synchronization process as such, as well as differences in individuals' synchronization behaviors. For example, studies on interaction processes in general have provided empirical evidence for (a) age-related differences (e.g., Coupland et al., 1988), (b) gender-related differences (e.g., Boker & Rotondo, 2002; Eskilson & Wiley, 1976; Megargee, 1969; Rotondo & Boker, 2002; Schmid Mast, 2004), and (c) personality-based differences (e.g., Smelser, 1961; Schmid Mast & Hall, 2003) in individuals' interaction styles. I suggest that based on these differences in individuals' behavior and related implicit role allocations between individuals during interactions, specific synchronization dynamics could be observed in interpersonal action synchronization processes. Interesting questions in this regard could be for example: Are there typical synchronization patterns that appear in all dyads (e.g., they start asynchronously and become synchronized over time)? Are some individuals more likely to lead (e.g., show a more stable tempo) while others are more predisposed to follow their interaction partner? More specifically, can one distinguish between "pace makers" and adjusting individuals in interpersonal action synchronization? Are there age-related or situation-specific differences in this implicit role allocation (e.g., do adults show behavior that facilitates younger children's interpersonal synchronization abilities, for example, are they able to restrict variability in children's behavior through stable behavior patterns)? And can implicit leading-following dynamics be associated with individual characteristics (e.g., submissive individuals adjust to dominant individuals) or gender-related roles (e.g., women adjust to men)? I propose that investigating the dynamics in basic goal-directed interpersonal action synchronization processes can enhance the understanding of the ability to synchronize with others as well as its development.

#### 4.5.2 Beyond Self-Report: Behavioral Indicators of Interpersonal Flexibility

Being able to adjust one's own actions to those of others across varying situations (*interpersonal flexibility*) is crucial for many interaction processes. Likewise, I argued that this ability is highly important in interpersonal action synchronization (see also Section 1.3.4). However, previous studies, including the present dissertation, assessed interpersonal flexibility through self-

and others' report, (questionnaire measures; e.g., Martin & Rubin, 1995; Paulhus & Martin, 1988). This method allows the examination of general abilities in interpersonal situations. I further suggest the direct investigation of behavioral indicators of interpersonal flexibility in social situations. For example, it may be informative to observe individuals in situations other than experimental conditions. Comprehensive observation of flexible adjustment in different situations (e.g., school, working processes) and with different individuals (e.g., relatives, strangers) could facilitate the understanding of interpersonal flexibility.

From an analytic perspective, examining dynamic structures during interpersonal action synchronization processes as proposed above can help to identify individuals who are especially skilled in synchronizing with others. Before that, it is necessary to define how flexibility appears in synchronization processes. For example, are individuals who give up their own preferred tempo and take over the tempo of the respective partner more flexible than others? Or alternatively, are individuals more flexible who, for example, show more stability in some interactions (i.e., leading when synchronizing with variable performance of children) and more variability in other situations (e.g., adjusting to more stable partners)? Future research needs to develop methods to assess interpersonal flexibility within synchronization processes and distinguish them from other behaviors like non-directed variability.

#### 4.5.3 Neural Correlates of Goal-Directed Interpersonal Action Synchronization and Its Development

I postulate that the investigation of *neural correlates* of goal-directed interpersonal action synchronization as a basis for various different interaction processes can certainly enhance the research on social interactions in general. Recently, social cognitive neuroscience has started to investigate brain activity underlying successful interactions with others (for review, see Singer, 2006; Frith & Wolpert, 2003; Montague et al., 2002; Singer & Frith, 2006). In the theoretical model of development, I claimed that goal-directed interpersonal action synchronization requires individuals' abilities to be aware of their own and others' actions and to anticipate them, which is based on the understanding and representation of others' intentions. Several studies have consistently provided evidence for the involvement of an area in the medial pre-frontal cortex (mPFC) during representation of others' thoughts, intentions, and beliefs (i.e., theory of mind; for review, see Gallagher & Frith, 2003; McCabe, Houser, Ryan, Smith, & Trouard, 2001; Rilling, Sanfey, Aronson, Nystrom, & Cohen, 2004). A related line of research has investigated the neural mechanisms underlying the ability to represent others' goals and intentions by simple observation of their motor actions. So-called *mirror neurons* have been found to be activated in the pre-motor

cortex of macaque brains both when the monkey performs a specific action itself and when it only observes the same action being performed by others (Rizzolatti, Fadiga, Gallese, & Fogassi, 1996).

A similar *common coding* of the production and perception of motor action has been described in the human brain (e.g., Blakemore & Decety, 2001; Rizzolatti, Fogassi, & Gallese, 2001). It is suggested that this mirror system underlies the ability to understand others' intentions by providing an automatic simulation of others' actions, goals, and intentions (e.g., Gallese, 2003; Gallese, Keysers, & Rizzolatti, 2004; Rizzolatti, Fadiga, Fogassi, & Gallese, 2002). For example, imitative behavior patterns indicate a common coding between observation and execution of actions (e.g., Decety & Chaminade, 2003; Meltzoff & Decety, 2003). These propositions are in line with the *theory of event coding* (see also Section 1.3.3), which also suggests a common representational medium for coding and storing both perceptual contents and action planning (Hommel et al., 2001). Neuroscientific findings of common perception–action coding as highlighted above are closely related to this theory (e.g., Tsai et al., 2006). Furthermore, in this line of research, neural correlates of *individuals'* timing and synchronization abilities have been examined by, among others, applying tapping paradigms (e.g., Chen et al., 2006; Ivry & Richardson, 2002; Jancke et al., 2000; Koski et al., 2002; Lewis, Wing, Pope, Praamstra, & Miall, 2004; Müller et al., 2000; Pollok et al., 2003). Very few studies also focused on neural correlates of *interpersonal* coordination processes (de Rugy, Salesse, Oullier, & Temprado, 2006; Tognoli et al., 2007).

However, as is true for research on goal-directed interpersonal action synchronization in general (see Section 1.2.2), none of the studies mentioned included developmental aspects. In line with empirical evidence from developmental brain sciences that indicates that brain regions differ with regard to their developmental change across the lifespan (e.g., Giedd et al., 1999; Raz et al., 2005), I suggest a developmental approach to the neuroscientific study of interpersonal action synchronization. Demonstrating which functional brain regions are most involved in interpersonal processes can further enhance the understanding of the lifespan development of interpersonal action synchronization. A better understanding of the neural correlates of these processes may help to explain individual and age-related differences in the ability to synchronize one's actions with those of others and, as a consequence, to interact with others in general.

## 4.6 Final Conclusions

The main aim of the present dissertation was the investigation of the development of goal-directed interpersonal action synchronization. Previous research described that non-intentional interpersonal synchronization appears very early in development (e.g., Condon & Sander, 1974a, 1974b) and occurs in many different social interactions throughout the lifespan (e.g., van Baaren et al., 2004). Although this implies its crucial role for various interaction processes, there was only limited research with regard to goal-directed interpersonal action synchronization, that is, individuals' ability to synchronize with others in order to reach a specific goal. In addition, there were no theoretical considerations or empirical investigations on the development of this ability. The present study therefore aimed at investigating three main research questions in line with lifespan-developmental theories (e.g., P. B. Baltes, 1987, 1990). These focused on (a) individual and age-related differences in individual antecedents of interpersonal action synchronization related to *life mechanics* and *life pragmatics*, (b) differences in interpersonal action synchronization related to the age composition of the dyads, and (c) possible consequences (i.e., subjective experience of the situation and the interaction partner) of interpersonal synchronization accuracy.

Applying a newly developed *dyadic drumming paradigm* to female same- and mixed-age dyads from four age groups (5, 12, 20–30, and 70–80 years), I found evidence that individuals' sensorimotor abilities (i.e., individuals' accuracy when synchronizing with a metronome) underlie interpersonal action synchronization. However, findings with regard to the social predictors were less clear in the present study: Although children with higher social skills showed higher synchronization accuracy when paired with other children, the expected association between flexibility and higher interpersonal action synchronization was not consistently supported. A possible explanation for this is that fewer social competencies are necessary in very controlled and artificial interpersonal synchronization situations (e.g., such as the dyadic drumming paradigm) as compared to naturally occurring social interactions. Furthermore, individual asynchrony (as an instance of sensorimotor abilities) was measured more directly than interpersonal flexibility (others' report questionnaires). Future studies focusing on the relevance of social competencies for interpersonal action synchronization processes should therefore include (a) more complex synchronization tasks and (b) more direct measures of social competencies (e.g., observation methods).

Dyads consisting of two adults (i.e., “younger adult – younger adult,” “younger adult – older adult,” and “older adult – older adult”) showed higher accuracy in synchronization than

dyads including children. In other words, interestingly, the dyadic drumming situation provided a synchronization context where younger and older adults showed similar levels of accuracy. In contrast to my hypothesis, younger adults' expected high functioning appeared not to be sufficient to compensate for possible lower interpersonal synchronization abilities in other age groups (e.g., children): Dyads including at least one younger adult did not always show higher synchronization accuracy than dyads without younger adults. This is possibly related to the finding that (a) younger and older adults showed comparable interpersonal synchronization abilities and (b) particularly younger children showed very low synchronization accuracy. Nonetheless, compared to pairings with their age peers, both child age groups showed the highest performance when synchronizing with older partners, especially with adults. This indicates that adults' abilities to synchronize with others facilitate the interpersonal synchronization process for children. A question for future research is whether this benefit for children is due to adults' flexibility or their stability in interpersonal synchronization performance. Both could be interpreted as signs of adults' adaptable and supportive behavior when interacting with children. However, differences in individuals' abilities were important, but not exclusively relevant for the interpersonal synchronization outcome: Part of the variance in interpersonal action synchronization accuracy related to differences between the dyadic age compositions still remained reliable after controlling for individual sensorimotor abilities and social competencies. This suggests that some source of variance derives directly from the interpersonal dynamic between the two individuals and so could not be captured completely by the chosen indicators of individuals' abilities. Future studies should therefore focus on the investigation of mutual dynamics that occur at a micro-level during interpersonal processes.

Finally, I was able to demonstrate the effect of interpersonal synchronization accuracy on the subjective experience of the interaction partner and the situation, that is, higher accuracy within a dyad was associated with a more positive experience between the interaction partners and even change in this experience from the beginning to the end of the interaction. I therefore concluded that the experience of synchronization accuracy influences the interpersonal evaluation process. This has been shown for various synchronization processes in individuals' everyday lives in previous research (e.g., Bernieri, 1988; Lakin & Chartrand, 2003; Tickle-Degnen & Rosenthal, 1987; van Baaren et al., 2004). The fact that this effect was even found in the very restricted experimental situation of the present study underlines the importance of interpersonal action synchronization for interpersonal experience.

To conclude, to a great extent, the findings supported the theoretical model of the development of goal-directed interpersonal action synchronization derived from lifespan-

developmental theories: Individual and age-related differences in the antecedents that pertain to life mechanics are related to the ability to synchronize one's own actions with those of others. The expected relationship between indicators of life pragmatics and interpersonal action synchronization accuracy was partly supported by the present study: There was first evidence that knowledge-based competencies may enhance interpersonal synchronization processes, at least for children. Interpersonal action synchronization abilities in turn are crucial for intra- as well as intergenerational interaction outcomes and their consequences. In view of the importance of interpersonal action synchronization for various social interactions in individuals' everyday lives, future research on social interaction processes can benefit from the findings of the present study. In particular, investigating developmental differences in individual antecedents and correlates of interpersonal action synchronization across the lifespan (e.g., by application of the dyadic drumming paradigm) can further illuminate variability in interaction processes and their outcomes. Goal-directed interpersonal action synchronization is highly important for our capability to interact in general and is proposed to have an adaptive function in various interaction processes. The ability to synchronize one's own actions with those of others allows individuals to reach interaction outcomes that are more than just the sum of all individual contributions. Referring back to the example of the jazz band in the introduction of this dissertation and to close with the lyrics of a famous jazz standard by Duke Ellington:

“It ain't the melody, it ain't the music.

There's something else that makes the tune complete.

It don't mean a thing, if it ain't got that swing.”