Research in Developmental Disabilities 85 (2019) 172–186

Contents lists available at ScienceDirect

Research in Developmental Disabilities

journal homepage: www.elsevier.com/locate/redevdis

Parent-child interaction: A micro-level sequential approach in children with a significant cognitive and motor developmental delay

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ARTICLE INFO

Keywords:
Interactive behavior
Parent-child interaction
Severe and multiple disabilities
Profound and multiple disabilities
Sequential analysis

ABSTRACT

Background & aims: Previous research indicates that young children with a significant cognitive and motor developmental delay show low levels of interactive engagement, their parents are generally responsive towards them and these variables are positively correlated. Adapting a micro-level approach, we aim to go beyond macro-level and correlational analyses by charting the frequency, intra-individual co-occurrence and inter-individual temporal dependency of specific interactive behaviors.

Methods & procedures: Twenty-nine parent-child dyads (with children aged 6–59 months) were video-taped during a 15-minute unstructured play situation. Based on a self-developed coding scheme, interactive behaviors were coded continuously and analyzed using a three-step sequential analysis approach.

Outcomes & results: Parents and children systematically combine either more socially-oriented or more object-oriented behaviors. Socially-oriented behaviors are less frequent in children, especially looking at and touching the partner occurs less. Socially- and object-oriented behavioral clusters are generally independent from each other and instigate/maintain the same type of behaviors in the interaction partner. While children's socially oriented behavior(al cluster)s seem to need a parental 'trigger', parents will more often independently engage with their child despite low child responsiveness.

Conclusions and implications: Further intervention-oriented research is needed to confirm this study's results and translate them into concrete guidelines for parents.

What this paper adds?

This paper aims to fill the striking gap of knowledge on the role of family and parenting factors in the development of young children with a significant cognitive and motor developmental delay. The parents of these children, and the professionals who guide them, experience of lot of uncertainty about recognizing and stimulating the interactional abilities of these children as well as about which parental interaction style is optimal for the child's development. This paper allows parents and practitioners to gain insight

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https://doi.org/10.1016/j.ridd.2018.11.008
Received 9 April 2018; Received in revised form 29 October 2018; Accepted 13 November 2018
Available online 17 December 2018
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into the specific co-occurrence and temporal dependency of parental and child interactive behaviors within this target group. Foremost, this study cautiously confirms that parents do have an influence on the (social) behaviors of their child. Also very important, this paper sets the stage for further intervention-oriented research to confirm this study's results and translate them into concrete guidelines for parents.

1. Introduction

A child's general development is the product of continuous dynamic interactions between the child and the experiences provided by his or her social settings (Lerner, Rothbaum, Boulos, & Castellino, 2002; Sameroff, 2010). Although interrelated with other (non-) familial influences and the broader context (Collins, Maccoby, Steinberg, Hetherington, & Bornstein, 2000), the most proximal social setting is formed by the child's parents (Bronfenbrenner, 1986; Lochman, 2004) or those who serve the parenting role in the child's life (Phillips & Shonkoff, 2000). As Bornstein (2001) states: "parenting constitutes an all-encompassing ecology for development" (p. 2). Even when young children spend most of their waking hours in child care, parents remain the most influential adults in their lives (Lochman, 2004; Phillips & Shonkoff, 2000).

Major developmental and learning theories view the parent's role in a slightly different way: from a guide that scaffolds the child's learning to a director who directly shapes the child's behavior (Charlesworth, 2013). However, essential in all theories is that the child learns throughout interactions, whether or not these are specifically and consciously aimed at promoting child development. The notion that the spontaneous daily interactions between parents and their children play a crucial role in child development is accentuated in the 'Developmental Systems Approach' (DSA) of Guralnick (2011) and the 'parenting model' of Mahoney and Nam (2011). Both conceptually and empirically grounded models are aimed at understanding how a child's development can be promoted in the context of early intervention, regardless of the child's developmental level. Guralnick (2011) specifically underlines that "meaningful and long-term intervention outcomes will depend on ensuring optimal family patterns of interaction, including parent-child transactions" (p. 15).

Parents' responsiveness is mentioned as the key construct related to the developmental value of parent-child interactions. Mahoney and Nam (2011) also state that in the current body of research on children with different types and/or levels of disability, most of the variability in parent's influence is associated with the degree to which they engage in "responsive interaction" with their children. A responsive parent can be described as a parent that is sensitive to the child's interests, shows supportive responses (i.e. they match the child's actions, requests and intentions) and is able to engage the child in the interaction (Mahoney, 2008). Although the concrete operationalization of responsiveness has varied widely across studies, this parenting characteristic consistently yields low to moderate correlations with child outcomes (Mahoney & Nam, 2011).

Mahoney and colleagues found that the effect of parents' responsiveness on children's development is fundamentally associated with its impact on children's use of pivotal behaviors that are the basis for developmental learning (Karaaslan, Diken, & Mahoney, 2013; Mahoney & Perales, 2003; Mahoney, Kim, & Lin, 2007; Mahoney & Perales, 2005). Pivotal behaviors are "behaviors that are central to wide areas of functioning such that a change in the pivotal behavior will produce improvement across a number of behaviors" (Koegel, Koegel, & Carter, 1999, p. 577). Originally studied within the field of autism spectrum disorder and further addressed by Mahoney and colleagues in relation to children with disabilities in general, child attentiveness and responsiveness to social and environmental stimuli as well as child's self-initiations are considered pivotal developmental behaviors (Koegel et al., 1999; Mahoney et al., 2007).

In the specific target group of young children with a significant cognitive and motor developmental delay (i.e. in analogy with 'Profound Intellectual and Multiple Disabilities' in adults; Nakken & Vlaskamp, 2007), very little is known on parent-child interaction and its influence on child functioning. In a recent literature review, Van keer and Maes (2016) did not find any peer-reviewed studies that linked parental behavior or broader family factors to child functioning (0–12 years) within this target group. The absence of research on this topic is very striking, since these children are restricted in their ability of independent exploration and thus highly dependent on their immediate caregivers to provide (opportunities for) meaningful experiences (Horn & Kang, 2012; Vlaskamp et al., 2011). Based on the results of this literature review, Van keer et al. (2017) studied the correlation between parental and child behavior in 25 dyads during a 10-minute free interaction. Parent's responsiveness within the interaction proved to be positively and significantly related to children's attention as well as initiation levels.

A limited amount of studies have tried to characterize (the perception of) interactive behavior of both parent and child within this target group, albeit focusing on one interaction partner. In two qualitative studies of Wilder and colleagues, parents perceived their own role in the interaction to be of a sensitive leading kind, but also perceived themselves to be less competent in understanding the child's communication and in directing and maintaining the child's attention, compared to parents of typically developing children (Wilder & Granlund, 2003; Wilder, Axelsson, & Granlund, 2004). Generally, parents aim for and aspire an increase of child attentiveness and responsiveness within their dyadic interaction (Wilder & Granlund, 2003). In the observational study of Van keer et al. (2017), parents were generally sensitive and responsive towards their children and the interactions were characterized by acceptance, warmth and enjoyment. Although parents 'guided' the interaction by offering toys and/or initiating activities, they did not often attempt to direct their child's behavior. This finding is surprising, since earlier research indicates that parents are more directive when children have lower developmental levels (Kelly & Barnard, 2000; Spiker, Boyce, & Boyce, 2002). Children with significant cognitive and motor limitations themselves (are perceived to) have difficulties with initiating interaction and maintaining attention (Wilder, 2008; Wilder & Granlund, 2003; Wilder et al., 2004). In general, children's interactive behaviors are less frequent, more subtle, difficult to read and/or idiosyncratic compared to typically developing children (Maes, Lambrechts, Hostyn, & Petry, 2007; Nakken & Vlaskamp, 2007; Phelvin, 2013). In the study of Van keer et al. (2017), children were moderately attentive, showing some

involvement and cooperation, but were rarely persistent in practicing actions and/or vocalizations. The children seldom initiated new or altered activities, but showed some attention to the adult.

Summarized, we know from these previous studies that parents of children with a significant cognitive and motor delay are generally responsive towards their child and, although children generally show low levels of interactive engagement, their attention and initiation levels are positively correlated with parental responsiveness. However, these results are either based on qualitative interviews or on a molar observational approach in which global ratings are applied to an entire observation (i.e. macro-level coding; Mesman, 2010). This molar approach allows for the incorporation of a wide range of content cues to evaluate the meaning and appropriateness of parental behavior but fails to assess the frequency of and linkages between specific behaviors (Bornstein, 2001) as well as the direction of these behavioral linkages. That is why, in this study, we chose to apply a molecular approach in which specific interactive behaviors are registered within very small time segments (i.e. micro-level coding), which allows for a more objective assessment of the association and temporal dependency between infant behavior and parental responses (Mesman, 2010).

In this study we aim to characterize the bidirectional relation between parental and child behaviors within the dyadic interaction. A three-step sequential analysis approach (Bodner, Kuppens, Allen, Sheeber, & Ceulemans, 2017) will be applied, by consecutively charting the frequency, the co-occurrence and the temporal dependency of the behaviors in both interaction partners. Since previous research has shown that the combined use of different (modalities of) behavior(s) is difficult for children with multiple disabilities, but elicits higher levels of attention and responding when used by the interaction partner (Neerinckx, 2015; Nijs, Vlaskamp, & Maes, 2016), co-occurrence of interactive behaviors will be analyzed intra-individually. Temporal dependency will be analyzed inter-individually to chart the effects of singular and combined interactive behaviors on the interaction partner's behaviors.

Detailed knowledge of these interactional features can be helpful in the creation of supportive interaction interventions within this specific target group, not only because of the focus on concrete observable (and modifiable) behavior, but also on important developmental child behaviors which are considered highly desirable elements of dyadic interaction by parents.

Our specific research questions are:

(1) Which types of interactive behaviors are frequently shown by parents and children, and which are not?
(2) Which types of interactive behaviors co-occur intra-individually?
(3) Which types of child interactive behaviors are temporally dependent on which types of parental interactive behaviors, and vice versa?

2. Method

2.1. Participants

Twenty-nine unique parent-child dyads participated in the study. They were recruited through hospitals, diagnostic centers, early intervention teams and specialized day care centers in Flanders (Belgium; $n = 12$) and the Netherlands ($n = 17$). Professionals within these organizations were asked (by mail and/or by telephone) to inform potential participants on the study and to bring them into contact with the researchers. Parents were free to choose whether the mother or father participated in the study. We included children between the age of 6 months and 4 years, who were at least spending their weekends and holidays with their family. We did not include children before the age of 6 months because clear indications of a significant developmental delay should be present and we wanted to respect the high emotional stress of parents in the first months after birth. A significant cognitive delay was operationalized using the 'Tandemlijst' (Stadeus, Windey, Vermeir, & Van Driessche, 1994). We included children functioning below a quarter of their chronological age, which is associated with the description of a profound intellectual disability (Grossman, 1973; Hogg, Foxen, & McBrien, 1981; Vig & Sanders, 2007). The Tandemlijst is specifically developed for young children with a developmental delay. It includes the developmental steps and milestones used in early intervention programs. By describing the cognitive developmental domain separately and in detail, the influence of the motor limitations on the estimation of cognitive functioning is minimized as much as possible. A significant motor delay was operationalized using the 'Gross Motor Function Classification System – Expanded & Revised' (GMFCS-E&R; Palisano, Rosenbaum, Bartlett, & Livingston, 2007). The GMFCS is specifically developed for and widely used in research on relatively young children with significant motor limitations and shows a good reliability and predictive value (Wood & Rosenbaum, 2000). Also, the instrument provides descriptions of motor abilities for different age bands, including 0–2, 2–4 and 4–6 years. We included children functioning at level IV or V (indicating a severe impairment) and, additionally, level III when the child was less than 2 years old (since combining level III, IV and V has a better predictive value at this young age; Gorter, Ketelaar, Rosenbaum, Helders, & Palisano, 2009). The presence of a significant developmental delay in both the cognitive and the motor domain was regarded as a necessary and sufficient inclusion criterion (Nakken & Vlaskamp, 2007). Children who only showed a significant delay in one of the two domains were not included. We formulated no criteria regarding the cause of the developmental delay and the presence of additional constraints (sensory disabilities, health problems, comorbid diagnoses such as ASS, etc.). Detailed background information on the parent-child dyads (provided by parents) is presented in Table 1.

2.2. Procedure and instruments

2.2.1. Data collection

Participating parent-child dyads were video-taped during a 15-minute unstructured play situation, at home or at the familiar day care facility of the child. Parents were instructed to engage with the child as they would normally do, but were not informed on the

Table 1
Sample characteristics.

Variable	*N*	%	Range	*M*	*SD*
Children	*29*				
Gender					
Male	8	28			
Female	21	72			
Age (in months)			12-58	37.74	12.58
Sensory impairments					
Reduced vision	12	41			
Blindness	2	7			
Reduced hearing	1	3			
Deafness	2	7			
Motor impairments					
Hypotonia	19	66			
Hypertonia	12	41			
Contractures	4	14			
Scoliosis	3	10			
Others	7	24			
Health problems					
Gastro-intestinal problems	16	55			
Heart problems	0	0			
Respiratory problems	8	28			
Epilepsy	20	69			
Others	9	31			
Use of feeding tube	15	52			
Etiology					
Genetic defect	14	48			
Perinatal asphyxia	2	7			
Acquired brain injury	1	3			
Unknown	12	41			
Parity					
Firstborn	11	38			
Not firstborn	18	62			
Parents	*29*				
Gender					
Male	8	28			
Female	21	72			
Age (in years)			26-54	34.38	5.80
Highest educational level					
Primary education	1	3			
Secondary education	6	21			
Higher education	22	76			
Activity status					
Working full-time	10	35			
Working part-time	11	38			
(Consciously) unemployed	8	28			
Families	*29*				
Number of family members			3-7	3.97	0.82
Parent(al figure)s			1-2	1.93	0.80
Children			1-5	2.03	0.78
One-parent households	2	7			
Reconstituted families	2	7			
Country of residence					
Belgium	12	41			
The Netherlands	17	59			

parental and child behaviors of interest to the study. Due to the significant (cognitive, motor and/or sensory) limitations and idiosyncratic needs and preferences of the children, we did not provide a standard set of toys. However, the researchers always ensured that parents had access to toys that were familiar to the child. Two cameras were used, each directed at one interaction partner: one was placed on a tripod and one was manually handled by the researcher in order to ensure optimal angle views. Because the observations related to this study were part of a broader project, parents and children were already familiarized with the researcher and the presence of camera equipment in the context of other test administrations.

2.2.2. Coding scheme

Based on an extensive analysis of the Child and Maternal Behavior Rating Scale of Mahoney (1998, 2008) and previous interactional research in diverse populations (a.o. Hostyn, 2011; Mahoney et al., 2007), a coding scheme for the concrete interactive behaviors of both

Table 2
Coding scheme for child and parental interactive behavior.

Interactive behavior	Examples
1. Looking behavior	
1a. Looking at the interaction partner	Initiating or establishing eye contact, visual monitoring/observing of partner's facial area
1b. Looking at an object/activity	Visual monitoring/observing of objects or an activity
2. Facial expression	Smiling, looking sad or uncomfortable, crying, looking angry, pouting lips, sticking out tongue,…
3. Touch	
3a. Direct touch	Simple touch on body part of interaction partner, caressing, hugging, kissing (with or without lip vibrations), stroking, …
3b. Touch with an object	Touching the person with an object (e.g. a toy), wiping the other person's mouth with a cloth,…
4. Object-related behavior	Showing or manipulating an object, touching an object/toy, taking an object/toy (away), biting on an object/toy,…
4a. Without sensory effects	Object-related behaviors when the manipulated object is not producing sounds, light effects or vibrations
4b. With sensory effects	Object-related behaviors when the manipulated object is producing sounds, light effects or vibrations
5. Movement	Moving specific body parts, pulling away, moving closer, falling backwards, actively overstretching the back,…
6. Physical support	Clearly supportive body postures (such as rocking position, stabilizing the pelvis with both hands,…), sitting on the lap, taking the hand and bring it to/manipulate an object,…
7. Gesture	Sign language, waving, pointing, nodding 'yes' or 'no', affirmative nod, shrug, thumbs up, clapping your hands ('bravo'),…
8. Active play behavior	Tickling, throwing or rolling a ball, peek-a-boo, clapping with the hands of the other person, portraying a song with the matching movements/gestures,…
9. Noise	Clapping, bouncing feet, tapping on the table or the chair you're sitting on with part(s) of the body, clapping/chattering teeth,…
10. Vocalization	Babbling, talking, screaming, laughing out loud, humming, clacking tongue, singing, crying, whining, whistling,…
Inadequate visibility	Instance where (a substantial part of) the interaction person's body is not visible on both video images

parents and children was developed. Interactive behaviors were broadly defined as behaviors that occur within the time frame of the interaction. Interactive behaviors could be directed to the interaction partner or be undirected. In this particular study, we take into account the undirected behaviors of both interaction partners because of two reasons. For one, parental responding to undirected child behaviors has substantial developmental value. It might be that certain child acts within the interaction are not (initially) communicative in any formal sense. However, by consistently overinterpreting and responding to the child's behavior, these acts are thought to eventually develop into functional communication responses (Carr et al., 2016; Daelman, 2003). Secondly, even when initial child or parental behavior is undirected, the interaction partner might respond to that particular behavior and instigate a directed behavioral sequence. Thus, undirected behavior inevitably forms an important part of parent-child interaction(al sequences). Additionally, it is very challenging to reliably assess the directionality of behavior in our target group, due to the children's motor impairments, possible visual impairments and idiosyncratic nature of their (social) utterances. When a substantial part of the person's face and/or body was not visible on both video images, the code 'inadequate visibility' was registered, allowing us to check the amount of missing data due to technical issues, positioning of the cameras or situational disturbances. A concise overview of the child and parental interactive behaviors is presented in Table 2. Extensive guidelines have been developed within a codebook that is available from the first author upon request.

2.2.3. Coding procedure

Child communication profiles were used to enhance the raters' understanding of the communicative utterances of the participating children. These profiles, filled in by parents, provided information on the ways a child usually communicates through gaze direction, facial expression, sound, posture and/or movement. In order to reduce observation effects, the first two minutes of the video-taped observations were not taken into account during the scoring process, as this was regarded as an adjustment period. For each dyad, the subsequent 10 min were coded. Coding was performed continuously. This means that behaviors were coded whenever they occurred and were stored in the software program 'The Observer XT 7.0' together with a time label accurate to the millisecond. Afterwards, the data sequence was split up into one-second intervals, corresponding to a partial interval coding system. This resulted in multivariate, binary time series data: each code was rated as 'present' (1) or 'absent' (0) for each 1-second interval.

2.2.4. Reliability

Reliability was primarily ensured by composing extensive and detailed coding guidelines, consistently applied by one coder (i.e. the first author) throughout all video observations. However, ten percent of each video fragment (i.e. random selection of a 1-minute interval) was double-coded as a reliability check. We included all dyads since each fragment is associated with specific challenges due to the idiosyncratic nature of the children's communicative utterances. The average exact agreement was 90% (91.4% for children and 88.6% for parents) and the average Cohen's kappa was .58 (.52 for children and .63 for parents), indicating an acceptable level of agreement (Haidet, Tate, Divirgilio-Thomas, Kolanowski, & Happ, 2009).

2.3. Data analysis

Data-analysis was carried out according to a three-step sequential analysis approach for binary dyadic data which allows for depicting three features of the studied interactive engagement behaviors: (1) frequency, (2) co-occurrence and (3) temporal dependency (Bodner et al., 2017). Firstly, the relative frequency (i.e. the proportion of time the behavior is shown) of all interactive

behaviors is presented, including several descriptive statistics (mean, standard deviation, median and range of scores).

Secondly, a *static* analysis of the intra-individual interactive behaviors -charting their contemporaneous relations- was carried out. The co-occurrence of behaviors was quantified by a corrected dyad-centered Jaccard similarity. The standard (i.e., non-corrected) Jaccard similarity (Jaccard, 1912) not only depends on how often two behaviors are shown simultaneously (i.e. within the same interval), but also on how often each of them is shown per se. Therefore, we computed corrected versions, Jac_{dy}^{Corr},

$$Jac_{dy}^{Corr} = \frac{Jac_{dy}^{Obs} - Jac_{dy}^{Exp}}{1 - Jac_{dy}^{Exp}}$$

that correct for the amount of co-occurrence that can be expected based on these marginal frequencies of the behaviors, much like Cohen's Kappa corrects for chance agreement between raters. Corrected Jaccards above zero thus indicate a co-occurrence that is higher than is expected by chance. Corrected Jaccard values were calculated for each dyad individually and subsequently, one-tailed one sample t-tests were performed to identify whether the mean corrected Jaccards differ significantly from zero at group level.

Thirdly, a *dynamic* analysis of inter-individual interactive behaviors -charting their temporal dependencies- was carried out. Temporal dependency of behaviors was quantified by corrected *dynamic* Jaccard similarities. These are equivalent to the corrected *static* Jaccards as described earlier, but take into account how often a behavior follows on another behavior (with)in the next interval (s) instead of within the same interval. Here also, one-tailed one sample *t*-tests were performed. Instead of focusing on a 1-second time lag, we computed the corrected *dynamic* Jaccard similarities of a 5-second window, indicating if the second behavior follows within 5 intervals after the first behavior. Few studies systematically vary the time lag to investigate the influence of varying temporal windows (Beebe et al., 2010). Because of the varying alertness levels and possible slower pace of information processing in people with multiple disabilities (Munde et al., 2012), it might be very important to provide them with the time and opportunity to process the interactive stimuli and respond to them. In previous research, responses often only emerged after a minimum of 3 s (Lima et al., 2012; Neerinckx, Vos, Van Den Noortgate, & Maes, 2014; Vos et al., 2013), while further initiatives were only registered after 5 s (Neerinckx, 2015; Neerinckx et al., 2014). For this reason, we also calculated the corrected *dynamic* Jaccards for a lagged 5-second window (i.e. intervals 6 to 10) to identify if the temporal dependency between behaviors can be characterized as long-term (present throughout the first and second window, i.e. interval 1 to 10), short-term (only present in the first window, i.e. interval 1 to 5) or delayed (only present in the second window, i.e. interval 6 to 10). Even though responses in our target group could very well show a greater delay, going beyond a 10-second interval did not seem appropriate, since this increases the risk that behaviors are incorrectly linked to other events from which they do not directly result.

For the *static* as well as the *dynamic* analysis, umbrella codes (looking and touching behavior) were disregarded. They did not provide additional information as the underlying codes represent unique separate behaviors. Only object-related behavior was included as an umbrella code in the analysis since the underlying codes (indicating the presence or absence of sensory effects) could also represent swift changes within one behavioral unit. For children, behaviors with extremely low frequencies (adjacent or equal to 0) were also disregarded.

3. Results

3.1. Relative frequency of interactive behaviors (research question 1)

The mean, standard deviation, median and range of the relative frequency of the child and parental interactive behaviors are

Table 3
Overview of the relative frequency of parental and child interactive behaviors.

	Parent			Child		
Interactive behaviors	Mean (SD)	Median	Range	Mean (SD)	Median	Range
1. Looking behavior	.92 (.12)	.97	.51-1.00	.45 (.28)	.43	.00-.97
1a. Looking at interaction partner	.77 (.19)	.83	.03-.98	.14 (.14)	.10	.00-.48
1b. Looking at object/activity	.31 (.17)	.25	.11-.77	.33 (.27)	.30	.00-.97
2. Facial expression	.33 (.18)	.33	.04-.67	.19 (.19)	.11	.00-.73
3. Touch	.27 (.21)	.21	.02-.74	.07 (.11)	.02	.00-.48
3a. Direct touch	.25 (.20)	.21	.02-.65	.07 (.11)	.02	.00-.48
3b. Touch with object	.03 (.04)	.01	.00-.20	.00 (.00)	.00	.00-.01
4. Object-related behavior	.43 (.24)	.42	.02-1.00	.29 (.21)	.27	.00-.85
4a. Without sensory effects	.27 (.19)	.22	.01-.73	.19 (.14)	.18	.00-.50
4b. With sensory effects	.19 (.17)	.15	.00-.88	.13 (.13)	.08	.00-.59
5. Movement	.50 (.13)	.49	.28-.92	.48 (.24)	.41	.06-.92
6. Physical support	.36 (.39)	.16	.00-1.00	.00 (.00)	.00	.00-.00
7. Gesture	.04 (.03)	.03	.00-.10	.00 (.00)	.00	.00-.02
8. Active play behavior	.06 (.09)	.01	.00-.31	.00 (.01)	.00	.00-.04
9. Noise	.01 (.04)	.00	.00-.23	.03 (.11)	.00	.00-.55
10. Vocalization	.58 (.24)	.59	.14-.97	.18 (.16)	.15	.01-.62
Inadequate visibility	.12 (.13)	.08	.00-.43	.16 (.19)	.08	.00-.63

presented in Table 3. Since the difference between mean and median frequency scores was generally small (M = 0.04 for both parental and child behavior), average scores are used to describe the results in-text.

On average, the parental behaviors that were shown most frequently throughout the interaction are: looking behavior (.92), vocalizations (.58) and movements (.50). These were also the most frequent behaviors shown by the children, although the presence of looking behavior (.45) and vocalizations (.18) was strikingly lower compared to the parents. More in detail, looking at an object/activity rendered comparable frequencies in parents (.31) and children (.33), while looking at the interaction partner differs greatly (.77 for parents and .14 for children). Facial expressions as well as object-related behavior were shown slightly more often by parents (.33 and .43) than by children (.19 and .29). A more striking difference occurred in relation to touching behavior, which was more frequent in parents (.27) than children (.07). In both groups, touching behavior consisted almost exclusively out of direct touches (.25 and .07) rather than touches with an object (.03 and .00). With an average relative frequency of .36, physically supporting the interaction partner is shown exclusively by parents. Further, low frequencies are evident for gestures, active play behavior and noise in both groups; although the first two are slightly higher for parents. Most of the discussed interactive behaviors showed rather large standard deviations, suggesting notable inter-individual differences in our study group. Particularly for physical support, the standard deviation (.39) as well as the difference between the mean and median score (.20) were strikingly large, suggesting large variability and the influence of a small number of extreme values.

3.2. Static analysis of intra-individual interactive behaviors (research question 2)

An overview of the average corrected intra-individual *static* Jaccard similarities, indicating systematic behavioral co-occurrence (i.e. higher than expected by chance), is provided in Table 4 (for parents) and Table 5 (for children).

In parents, looking at the child, facial expressions and vocalizations were all significantly related to each other. Direct touch was significantly related to looking at the child and vocalizations. Further, looking at an object/activity and object-related behavior (whether or not sensory effects were present) were mutually strongly associated. Touching the partner with an object was also significantly related to both of these categories, although less pronounced. The category of vocalizations showed significant relations with all interactive behaviors except for looking at an object/activity, touching the partner with an object and object-related behavior. Gestures and active play behavior were both significantly associated with three behavioral categories: looking at the partner, facial expression and vocalizations.

In children, significant mutual relations were found between looking at the interaction partner, facial expressions and vocalizations, with the latter two showing the strongest relationship. Child movement was also significantly related to facial expression and vocalization, but not to looking at the interaction partner. Object-related behavior (whether or not sensory effects were present) was exclusively and significantly associated with looking at an object/activity. Direct touch as well as noise did not show any significant relations with other behaviors.

3.3. Dynamic analysis of inter-individual interactive behaviors (research question 3)

Since the results of the *static* analyses (research question 2) showed that two behavioral clusters were evident in parents as well as children, these were added in the *dynamic* analyses as extra variables. A socially-oriented behavioral cluster (consisting of looking at the interaction partner, facial expression and vocalization) is further referred to as 'social cluster' and an object-oriented cluster (consisting of looking at the object/activity and object-related behavior) is further referred to as 'object cluster'. These cluster codes were only registered as present within a 1-second interval whenever all behaviors within the cluster were present in that specific interval. For parents only, additional cluster codes were registered when a direct touch or touch with an object was present together with the behaviors of the basic social or object cluster, respectively. The mean, standard deviation, median and range of the relative

Table 4
Overview of the corrected static Jaccard similarities of parental interactive behaviors.

Parental interactive behaviors	P_1a	P_1b	P_2	P_3a	P_3b	P_4	P_4a	P_4b	P_5	**P_6**	**P_7**	**P_8**	**P_9**	**P_10**
1a. Looking at interaction partner	–	−.11	.08***	.02**	.00	−.03	−.01	−.01	−.01	−.01	.00**	.01**	.00*	.04**
1b. Looking at object/activity	−.11	–	−.06	−.03	.01*	.14***	.07**	.11***	.07***	.02*	−.01	−.02	.00	−.02
2. Facial expression	.08***	−.06	–	.01	.00	−.01	.00	.00	.00	−.02	.02**	.04***	.00	.07***
3a. Direct touch	.02**	−.03	.01	–	−.01	−.07	−.05	−.04	.01*	.00	.00	−.01	.00	.02*
3b. Touch with object	.00	.01*	.00	−.01	–	.06**	.03*	.06**	−.01	.00	−.01	−.01	.00	.00
4. Object-related behavior	−.03	.14***	−.01	−.07	.06**	–	.55***	.34***	−.01	.02	−.01	−.03	.00	−.03
4a. Without sensory effects	−.01	.07**	.00	−.05	.03*	.55***	–	−.03	.00	.00	−.01	−.02	.00	.01
4b. With sensory effects	−.01	.11***	.00	−.04	.06**	.34***	−.03	–	−.01	.03	−.02	−.02	.00	−.03
5. Movement	−.01	.07***	.00	.01*	−.01	−.01	.00	−.01	–	.01	−.01	−.02	.00*	.05***
6. Physical support	−.01	.02*	−.02	.00	.00	.02	.00	.03	.01	–	−.01	−.01	.00	.02*
7. Gesture	.00**	−.01	.02**	.00	−.01	−.01	−.01	−.02	−.01	−.01	–	−.01	.03	.02***
8. Active play behavior	.01**	−.02	.04***	−.01	−.01	−.03	−.02	−.02	−.02	−.01	−.01	–	.00	.02**
9. Noise	.00*	.00	.00	.00	.00	.00	.00	.00	.00*	.00	.03	.00	–	.00*
10. Vocalization	.04**	−.02	.07***	.02*	.00	−.03	.01	−.03	.05***	.02*	.02***	.02**	.00*	–

*$p < .05$, **$p < .01$, ***$p < .001$.

Table 5
Overview of the corrected static Jaccard similarities of child interactive behaviors.

Child interactive behaviors	C_1a	C_1b	C_2	C_3a	C_4	C_4a	C_4b	C_5	C_9	C_10
1a. Looking at interaction partner	–	−.06	.03**	.01	.00	.01	−.01	.00	.00	.01*
1b. Looking at object/activity	−.06	–	.00	−.01	.07***	.02*	.06***	.02	.01	−.02
2. Facial expression	.03**	.00	–	−.01	−.01	.00	−.01	.04***	.01	.11***
3a. Direct touch	.01	−.01	−.01	–	−.02	−.02	−.01	.00	−.01	.01
4. Object-related behavior	.00	.07***	−.01	−.02	–	.60***	.35***	−.01	.00	−.02
4a. Without sensory effects	.01	.02*	.00	−.02	.60***	–	.00	−.02	.00	.00
4b. With sensory effects	−.01	.06***	−.01	−.01	.35***	.00	–	.01	.00	−.02
5. Movement	.00	.02	.04***	.00	−.01	−.02	.01	–	.01	.04***
9. Noise	.00	.01	.01	−.01	.00	.00	.00	.01	–	.00
10. Vocalization	.01*	−.02	.11***	.01	−.02	.00	−.02	.04***	.00	–

*$p < .05$, **$p < .01$, ***$p < .001$.

frequency of the behavioral clusters are presented in Table 6. In parents, the relative frequency of the social and object cluster is comparable (.22 and .19 respectively), but the combination with touch is far less frequent (.07 and .01 respectively). Children seldom show all behaviors of the social cluster simultaneously (.02); the relative frequency of the object cluster is notably higher (.12).

An overview of the average corrected inter-individual *dynamic* Jaccard similarities, indicating the temporal dependency of behaviors, is provided in Tables 7a and 7b for child behavior following on parental behavior and in Tables 8a and 8b for parental behavior following on child behavior. Tables 7a and 8a present the results related to the first 5-second window, Tables 7b and 8b represent the lagged 5-second window (i.e. seconds 6–10). We will discuss the temporal dependency by indicating which behaviors systematically 'precede/predict' or 'follow on' each other, but do not necessarily imply a causal relationship. The discussed (lack of) temporal dependency can be considered as long-term (present in both 5-second windows), unless otherwise specified. Results that are explicitly described as short term are only present in the first 5-second window, while results described as delayed are only present in the second window.

Considered separately, both behavioral clusters (socially-oriented as well as object-oriented) are temporally dependent on an inter-individual level. This means that a behavioral cluster shown by one partner systematically precedes and follows on the same type of cluster in the other partner. These interdependencies can be characterized as long-term, except for parent's social cluster following on the child's social cluster (short-term). Social and object clusters are not temporally dependent on each other. In general, the additional presence of touch does not seem to have an added value in predicting a behavioral cluster of the interaction partner.

One partner's behavioral cluster not only systematically precedes the same type of behavioral cluster in the interaction partner, but also the individual behaviors within that cluster. However, a child's social cluster does not seem to predict parental vocalizations, only parental looking (long-term) and facial expression (short-term). Also, a child's object cluster only predicts parental object related behavior with sensory effects, not without sensory effects. Additionally, with regard to behaviors that are not part of the related cluster, a parent's social cluster predicts child movement (long-term) and child noise (delayed).

Further, one partner's individual behaviors within a cluster also systematically precede the related behavioral cluster in the interaction partner. However, one partner's vocalizations only predict the other partner's social cluster within the first 5-second window (short-term), while looking at the partner and facial expression show a long-term predictive value. Additionally, with regard to behaviors that are not part of the related cluster, parental gestures predict a child's social cluster (short-term). Further, parent's object related behavior without sensory effects only has a short-term predictive value related to a child's object cluster, while object-related behavior with sensory effects has a long-term predictive value. A child's facial expression precedes a parent's object cluster, but this temporal dependency is delayed.

Next, we will discuss the temporal dependencies between individual behaviors. All parental behaviors related to the social cluster (looking at the partner, facial expression and vocalizations) systematically precede all child behaviors within the same cluster, with parental vocalization showing a primarily short-term predictive value. However, the results show one exception: parental looking (at the child) does not systematically precedes child looking (at the parent). In the other direction, looking at child behavior preceding parental behavior (within the social cluster), the results are less clear. Parent's facial expression is the only behavioral category that is systematically preceded by all child behaviors within the social cluster (short-term). The child's facial expression precedes parent's facial expression (long-term) and parent's looking at the child (delayed). Importantly, here also, child looking

Table 6
Overview of the relative frequency of the identified intra-individual behavioral clusters.

	Parent			Child		
Interactive behaviors	Mean (SD)	Median	Range	Mean (SD)	Median	Range
11a. Social cluster	.22 (.15)	.20	.00-.58	.02 (.04)	.00	.00-.20
11b. Social cluster + direct touch	.07 (.07)	.05	.00-.21			
12a. Object cluster	.19 (.15)	.15	.01-.77	.12 (.13)	.07	.00-.56
12b. Object cluster + touch with object	.01 (.02)	.00	.00-.08			

Table 7a
Overview of the corrected dynamic Jaccard similarities of child behavior (horizontal) following on parental interactive behavior (vertical) within a 5-second window.

Parental interactive behaviors	C_1a	C_1b	C_2	C_3a	C_4	C_4a	C_4b	C_5	C_9	C_10	C_11a	C_12a
1a. Looking at interaction partner	.02	−.03	.02*	.00	−.02	−.02	−.01	.02	.00	.04***	.01**	−.02
1b. Looking at object/activity	−.03	.09***	−.02	−.01	.09***	.06**	.08***	.00	.00	−.03	−.01	.08***
2. Facial expression	.02*	.00	.06***	−.01	.00	.00	−.01	.02*	.00	.05***	.03**	−.01
3a. Direct touch	.01	−.03	.00	.02	−.02	−.02	−.02	−.01	.00	.01	.00	−.01
3b. Touch with object	−.01	.00	.00	−.01	.01	.00	.00	−.01	.00	−.01	.00	.00
4. Object-related behavior	−.02	.13***	.02	−.02	.10**	.05*	.07**	.00	.00	−.02	.00	.06**
4a. Without sensory effects	.00	.09***	.01	−.01	.05*	.07**	.00	.01	.00	−.01	.00	.03*
4b. With sensory effects	−.01	.05***	.01	−.01	.07**	.00	.12***	.00	.00	−.01	.00	.06*
5. Movement	.02	−.01	.01	.01*	−.01	−.01	−.01	.02	.00	−.01	.00	.00
6. Physical support	.01	−.02	.00	.06**	.00	−.01	.03	−.02	−.01	−.01	−.01	−.01
7. Gesture	.01	−.01	.01*	.00	.00	.01	.00	.00	.00	.01*	.02*	−.01
8. Active play behavior	.01	−.01	.02*	.02	−.02	−.01	−.01	−.01	.00	.01*	.01	−.02
9. Noise	.00	−.00	.01*	.00	.00	.00	.00	.00	.03	.00	.00	.00
10. Vocalization	.02**	−.01	.02*	.01*	−.02	.00	−.03	.00	.00	.02*	.01*	−.01
11a. Social cluster	.03**	−.02	.06***	.00	−.02	.00	−.03	.02*	.00	.05***	.03**	−.02
11b. Social cluster + direct touch	.01*	−.02	.02*	.00	−.01	−.01	−.02	.00	.00	.01*	.01	−.01
12a. Object cluster	−.02	.07***	−.01	.00	.08***	.04*	.07***	−.01	.00	−.03	−.01	.06***
12b. Object cluster + touch with object	−.01	.00	.00	−.01	.01	.00	.00	.00	.00	.00	.00	.00

*$p < .05$, **$p < .01$, ***$p < .001$.

Table 7b
Overview of the corrected dynamic Jaccard similarities of child behavior (horizontal) following on parental interactive behavior (vertical) within the lagged 5-second window.

Parental interactive behaviors	C_1a	C_1b	C_2	C_3a	C_4	C_4a	C_4b	C_5	C_9	C_10	C_11a	C_12a
1a. Looking at interaction partner	.01	−.02	.02*	.00	−.02	−.02	−.00	.02	.00	.03**	.01**	−.01
1b. Looking at object/activity	−.02	.07***	−.01	−.01	.08***	.05**	.07***	.00	.00	−.01	−.01	.06***
2. Facial expression	.02**	.00	.04***	.00	.00	.01	−.02	.01	.00*	.03***	.02**	−.01
3a. Direct touch	.01	−.02	.00	.01	−.02	−.02	−.02	−.01	.00	.00	−.01	−.01
3b. Touch with object	−.01	.00	.00	−.01	.01*	.01	.01*	−.01	.00	.00	.00	.00
4. Object-related behavior	−.01	.11***	.01	−.01	.10**	.05*	.07**	.00	.00	−.01	.00	.05**
4a. Without sensory effects	.00	.09**	.01	.00	.05*	.06*	.01	.00	.00	.00	.00	.03
4b. With sensory effects	−.01	.04**	.01	−.01	.07**	.01	.09**	.00	.00	.00	.00	.05*
5. Movement	.01	.00	.01	.01	−.01	−.01	.00	.02*	.00	−.01	.00	.00
6. Physical support	.00	−.02	.00	.05*	.00	−.01	.02	−.01	−.01	.00	−.01	−.01
7. Gesture	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8. Active play behavior	.01	−.01	.01*	.02*	−.01	−.01	−.01	.00	.01	.01*	.01	−.01
9. Noise	.00	.00	.01	.00	.00	.00	.00	.00*	.01	.00	.00	.00
10. Vocalization	.01	−.02	.02*	.01*	−.03	.00	−.03	.00	.00	.01	.00	−.02
11a. Social cluster	.02*	−.02	.03***	.00	−.02	.00	−.03	.01*	.01*	.03**	.02**	−.02
11b. Social cluster + direct touch	.01*	−.01	.02*	.00	−.02	−.01	−.02	.00	.00	.00	.01	−.01
12a. Object cluster	−.01	.05***	.00	−.01	.07***	.04*	.06***	.00	.00	−.02	−.01	.05**
12b. Object cluster + touch with object	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

*$p < .05$, **$p < .01$, ***$p < .001$.

(at the parent) does not systematically precedes parental looking (at the child).

Direct touch does not seem to add predictive value to the social behavioral cluster, but does show some temporal dependencies on the level of individual behaviors. Direct touch by the child is systematically preceded by parental movement (short-term), vocalization (long-term) and active play behavior (delayed). Parental physical support and child touch are mutually predictive. Parental touch does not predict any child behavior, but is systematically preceded by child touch (long-term) and child looking at the parent (short-term).

For parents as well as for children, the behavioral categories within the object cluster (looking at an object/activity and object-related behavior) are all mutually predictive. However, object-related behavior of one partner only systematically precedes or follows on the similar type of behavior (i.e. with or without sensory effects) of the other partner, with the presence of sensory effects rendering stronger dependencies. Object-related behavior with sensory effects of the child also systematically follows on parental touch with an object, albeit delayed. Other delayed dependencies are evident for child's facial expression preceding parental touch with an object as well as preceding parent's object-related behavior with sensory effects.

Child movement systematically precedes parental movement (long-term), while parental movement shows a delayed predictive value for child movement. Both parental movement and child movement are systematically preceded by the partner's facial expression (short-term). The two higher level behaviors (parental gestures and active play behavior) predict children's facial expression and vocalizations, but the predictive value of gestures is short-term. The other way around, parental gestures are systematically

Table 8a
Overview of the corrected dynamic Jaccard similarities of parental behavior (horizontal) following on child interactive behavior (vertical) within a 5-second window.

Child interactive behaviors	P_1a	P_1b	P_2	P_3a	P_3b	P_4	P_4a	P_4b	P_5	P_6	P_7	P_8	P_9	P_10	P_11a	P_11b	P_12a	P_12b
1a. Looking at interaction partner	.00	−.03	.03*	.02*	.00	−.02	−.02	−.02	.00	.01	.02**	.01	.00	.00	.04**	.02*	−.03	−.01
1b. Looking at object/activity	.01	.08***	.01	−.04	.01	.10***	.08**	.08***	−.02	−.02	−.01	−.01	.00	−.01	−.01	−.03	.08***	.00
2. Facial expression	.00	.00	.05***	.00	.01	.01	.01	.02	.01*	−.01	.01*	.02*	.00	.01*	.05***	.03*	.01	.01
3a. Direct touch	.00	−.01	.00	.02*	−.01	−.02	−.01	−.01	.00	.06**	−.01	.01	.00	.00	.00	.01	−.01	−.01
4. Object-related behavior	.00	.09***	.01	−.02	.01	.07**	.04*	.09**	.00	.00	.00	−.01	.00	−.02	−.01	−.02	.08***	.01
4a. Without sensory effects	−.01	.04**	.01	−.01	.00	.03*	.05**	.02	.00	−.02	.01	.00	.01	.00	.00	−.01	.04*	.00
4b. With sensory effects	.00	.06***	.00	−.01	.01	.04*	−.01	.10***	.00	.02	.00	−.01	.00	−.02	−.01	−.02	.05**	.00
5. Movement	.01	.02*	.02	−.01	−.01	.02	.02	.00	.02**	−.02	.00	−.01	.00	.00	.01	−.01	.02	−.01
9. Noise	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00
10. Vocalization	.01**	−.01	.02**	.00	−.01	−.01	.00	−.01	.00	.00	.02*	.01	.00	.01**	.03**	.02**	−.01	−.01
11a. Social cluster	.00**	.00	.01*	.01	.01	.00	.00	.00	.00	−.01	.01	.00	.00	.00	.01*	.01*	.00	.00
12a. Object cluster	.00	.05**	.00	−.02	.00	.03*	.02	.07**	.00	−.01	.00	−.01	.00	−.01	−.01	−.02	.05**	.00

*$p < .05$, **$p < .01$, ***$p < .001$.

Table 8b
Overview of the corrected dynamic Jaccard similarities of parental behavior (horizontal) following on child interactive behavior (vertical) within the lagged 5-second window.

Child interactive behaviors	P_1a	P_1b	P_2	P_3a	P_3b	P_4	P_4a	P_4b	P_5	P_6	P_7	P_8	P_9	P_10	P_11a	P_11b	P_12a	P_12b
1a. Looking at interaction partner	.00	−.02	.01	.01	.00	−.02	−.02	−.01	.00	.01	.01*	.01	.00	.01	.02*	.01	−.02	−.01
1b. Looking at object/activity	.01	.07***	.02	−.03	.01	.08***	.06**	.07***	−.02	−.02	−.01	.00	.00	−.02	−.01	−.02	.06***	.00
2. Facial expression	.01*	.01	.02*	.00	.02*	.02*	.01	.02*	.00	−.01	.01	.01	.00	.00	.02*	.01	.02**	.01
3a. Direct touch	.00	−.01	.00	.02*	−.01	−.02	−.01	−.01	.00	.05*	−.01	.00	.00	.00*	.00	.01	−.01	−.01
4. Object-related behavior	.00	.07***	.01	−.02	.00	.08**	.05*	.08**	.00	−.01	.00	−.01	.00	−.02	−.01	−.01	.07***	.00
4a. Without sensory effects	.00	.04**	.01	−.01	.00	.04*	.05**	.03	.00	−.02	.00	.00	.00	−.01	.00	−.01	.04**	.00
4b. With sensory effects	.00	.05**	.00	−.00	.00	.04**	.00	.08**	.00	.01	.01	−.01	.00	−.01	−.01	−.01	.04**	−.01
5. Movement	.00	.01	.00	−.01	.00	.01	.02	.01	.02*	−.01	.00	−.01	.00	.00	.00	−.01	.01	.00
9. Noise	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
10. Vocalization	.01	−.01	.00	.01	.00	−.01	−.01	−.01	.00	−.01	.01*	.01	.00	.00	.00	.00	−.01	.00
11a. Social cluster	.00*	.00	.01	.00	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.00	.00
12a. Object cluster	.00	.03**	.01	−.01	.00	.03**	.02	.06**	−.01	−.01	.00	−.01	.00	−.01	−.01	−.01	.03**	.00

*$p < .05$, **$p < .01$, ***$p < .001$.

preceded by children's looking behavior (long-term), facial expressions (short-term) and vocalizations (long-term). Parent's active play behavior is only systematically preceded by children's facial expression (short-term).

4. Discussion

4.1. Conclusions

Generally, our results confirm a discrepancy between parent's and children's social engagement within the interaction (Phelvin, 2013; Wilder, 2008). Parents within our study group show consistent visual attention during a 10-minute unstructured play situation, either by looking at an object, an activity or their child. Children, on the other hand, are visually attentive less than half of the time, looking twice as much at an object or activity than at their parent. Even so, while parents are strikingly more attentive to the child than the other way around, they are comparably attentive to objects or activities within the context of the interaction. Further, although parents and children both show notable movements for approximately half of the interaction's time, this does not imply comparable strength, speed or quality of the movements. Also, vocalizations, facial expressions, touch and object-related behavior are clearly present in the behavioral repertoire of both groups, although more frequent in parents than children. Parents vocalize more than half of the time and directly touch their interaction partner for a quarter of the time, both roughly three times more than the children do. Further, parents spend a highly variable amount of time physically supporting their child. Higher-level behaviors, such as gestures and active play behavior, are only shown sporadically by parents and are rarely shown by a child in our target group. This might indicate that parents adapt their behavior to the child's developmental level, although we cannot be sure if these higher-level behaviors would indeed be more frequent in play interactions with typically developing children.

Throughout the interaction, parents seem to look, touch, move, manipulate objects, vocalize and show a facial expression at the same time on a regular basis. Overall, parents show two different types of behavioral combinations. A more socially-oriented cluster of behaviors consists of the parents looking at their child, vocalizing and showing a facial expression, sporadically complemented by touching the child. A more object-oriented cluster of behaviors consists mainly of looking at and manipulating the object, sporadically complemented by touching the child with the manipulated object. Surprisingly, parents systematically vocalize in combination with all interactive behaviors, except for the behaviors in the object-oriented cluster. Higher-level behaviors such as gestures and active play behavior are systematically combined with socially-oriented behaviors (looking, showing a facial expression and vocalizing).

As expected, children's interactive behaviors are less frequent and differentiated than those of their parents. However, even though the combined use of different (modalities of) behavior(s) is difficult for children with multiple disabilities (Nijs et al., 2016), this study shows that these children do -to some extent- combine different types of behavior in interaction with their parents. Overall, children combine facial expressions with vocalizations, whether or not complemented by looking at the parent. Thus, children show a comparable socially oriented cluster of behaviors as their parents do, although the relation with looking at the partner is less pronounced (which might explain the low frequency of the complete social cluster) and children do not combine these (or any) behaviors with direct touch. In addition, while the results show that children are able to move in combination with several other behaviors, they only systematically combine movement with facial expression and vocalizations. Further, children also show a clear object-oriented cluster of looking at and manipulating an object, although slightly less frequent than parents.

Showing a socially- or object-oriented cluster of behaviors seems to instigate and/or maintain the same type of behavioral cluster in the interaction partner. However, the socially-oriented behavior(al cluster)s of parents do seem to be more independent from the child's behavior than vice versa: children's socially-oriented behaviors seem to need a parental 'trigger', while parents will more often socially engage with their child on their own initiative. Solely looking at the partner does not seem to trigger looking behavior of the other partner in neither child nor parent. To trigger this behavior, showing a complete socially-oriented behavioral cluster is most effective on the long-term, especially for the children. This confirms earlier research suggesting that the combined use of different (modalities) of behavior(s) by the interaction partner elicits higher levels of attention in persons with multiple disabilities (Neerinckx, 2015). However, vocalizations on their own also prove to be effective in eliciting looking behavior on the short-term. In general, vocalizations seem to trigger rather short-term social reactions in the interaction partner, compared to looking behavior and facial expression. This conclusion is slightly more pronounced in parents, in which vocalization as a reaction itself can also be characterized as short-term and more independent of the child's behavior compared to the other social behaviors. Further, parental touch seems to be triggered by social initiatives from the child, i.e. touching and/or looking, but does not seem to have any predictive value towards subsequent child behavior (on its own or within the context of a social behavioral cluster). This finding is rather surprising, since touch is assumed to be a core interactive strategy in persons with multiple disabilities (Forster & Iacono, 2008; Hostyn, Daelman, Janssen, & Maes, 2010), partly because this modality is not affected by the frequent visual and auditory impairments in this target group. However, even if parental touch does not trigger child responses, touch is likely to be essential with regard to other outcomes such as the child's physical, social and emotional wellbeing (Dobson, Upadhyaya, Conyers, & Raghavan, 2002).

Socially-oriented and object-oriented behaviors are not systematically combined by either of the interaction partners and do not show notable predictive value inter-individually. So, parent-child interaction does seem to be either socially-oriented or object-oriented rather than a combination of both at the same time. When the interaction is object-oriented, looking at and manipulating the object are behaviors that mutually instigate and maintain each other in parents and children. So, contrary to socially-oriented behavior(al cluster)s, there seems to exist a more balanced eliciting process between both partners when it comes to object-oriented behavior(al cluster)s. This (together with the comparable frequencies of object-oriented behaviors in both partners) might indicate that parents are more persistent in showing (and trying to elicit) social behavior, compared to object behavior, even when children

are little responsive. These results confirm earlier research indicating that parents aim for an increase of general child (social) attentiveness and responsiveness within their dyadic interaction (Wilder & Granlund, 2003), rather than trying to stimulate concrete (object-related) skills. Further, object-related behavior only triggers behavior of the same type (i.e. either with or without sensory effects) in the other person. This conclusion can of course be influenced by the characteristics of the object that is being handled (i.e. if the object is meant to or easily prone to provide sensory effects such as a rattle). However, object-related behavior with sensory effects seems to be more easily triggered and/or maintained by the interaction partner and, in children, shows a longer-lasting effect on their object-oriented behavioral cluster. Children's object-related behavior with sensory effects is also sometimes triggered by parents touching them with the object, albeit delayed. Further, parents seem to use gestures only when children are socially attentive towards them, while active play behavior seems to be a more independent behavior. Both of these higher-level behaviors trigger social behaviors in the child, primarily facial expressions and vocalizations, with active play behavior showing a longer-lasting effect and a delayed effect on child touch. These striking results regarding active play behavior as well as the additional value of sensory effects in object-related behavior suggests that the combination of different (modalities of) stimuli might elicit higher levels of responding in children with multiple disabilities, which is comparable to our conclusion with regard to the social cluster (Neerinckx, 2015).

4.2. Strengths and limitations

Going beyond correlational analyses and attempting to disentangle the direction(s) in which child and parental behavior influence one another is the major strength of this study. The richness of the data set (i.e. information on the presence or absence of several behaviors on 600 different time points for each individual) allows for a reliable statistical analysis, which is often a great challenge in research on our specific target group due to small sample sizes. In this study, we used a recently proposed data analysis technique based on multivariate, binary time series data (Bodner et al., 2017). A great advantage of this technique is the possibility to combine different codes post-hoc, which is ideal for explorative research. Also, working with 1-second intervals, the precise registration of the beginning (start-code) and end of a behavior (stop-code) becomes less crucial. This decreases the influence of (differences in) the coder's reaction time on the results and might result in more reliable data when the demarcation of behaviors is challenging, as is the case in our target group. Important to note, since each code was rated as 'present' (1) or 'absent' (0) for each 1-second interval, it is possible that swift changes between two behaviors are registered as co-occurring (even when they are defined as mutually exclusive, e.g. looking at the partner and object).

Of course, this study's results need to be interpreted with caution. For one, the non-randomized sampling method impedes generalizability. Since we primarily recruited participants indirectly through professionals, our insight into a possible selection bias and the reasons behind non-participation is fairly limited. In addition, children with severe and multiple disabilities often show fluctuations in their behavioral patterns over time (Goldbart, 1994; Munde, Vlaskamp, Ruijssenaars, & Nakken, 2011). Therefore, the momentary observation of children's interactive behaviors might not be fully representative of the child's general functioning. Also, parent's behavior could be influenced by the presence of the camera's and/or the researcher. However, by providing clear instructions and incorporating adjustment time (during data collection as well as coding), we attempted to constrain possible bias.

Further, the results of all analyses within this study were summarized at group-level in order to formulate generalized conclusions. This study's target group is defined to be heterogeneous regarding the cause of the developmental delay and the presence of additional constraints (cf. Profound Intellectual and Multiple Disabilities, Nakken & Vlaskamp, 2007). However, the behavioral frequencies as well as the strength and direction of behavioral linkages could be influenced by child characteristics (such as etiology and additional sensory impairments or health issues). Two major challenges impede the incorporation of these variables into the data analysis. First of all, due to the complex impairments of the children, an objective and valid assessment of sensory impairments or health issues (e.g. epilepsy) is often not possible. In that regard, sensory impairments tend to go unnoticed in people with ID (Evenhuis, Theunissen, Denkers, Verschuure, & Kemme, 2001). The cause of the developmental delay is often unknown or only partially discovered. A second -related- challenge is the size of the subsamples, which are too small to reliably assess. A valuable solution would be to conduct case studies, however, this is beyond the scope of current study. To improve the generalizability of the results, the differences in visual functioning were taken into account within the coding scheme, for example by coding general 'looking behavior' (i.e. visual monitoring/observing of partner's facial area) instead of established eye contact; which is more applicable in children with visual impairments. In the same regard, interactive behaviors could be directed to the interaction partner or be undirected, since a.o. visual impairments compromise a reliable assessment of directionality. Also, in the used method of analysis, the Jaccard-measures are corrected for the amount of co-occurrence and temporal dependency that can be expected based on the marginal frequencies of the behaviors. Since this correction is applied at dyad-level instead of group-level, we thus account for heterogeneity within the group in marginal frequencies (i.e. the Jaccard values are not heavily influenced by outliers in frequency, for example looking behavior in a child that is considered to be blind).

To strengthen the validity of the results, it was specifically and strongly stated that the coder could never make assumptions on the presence or absence of behaviors in case of inadequate visibility. The mean relative frequency of inadequate visibility seems rather high (.12 for parents and .16 for children). However, further analyses show that the interaction partners seldom moved entirely out of sight, with a mean relative frequency of 0.02 for parents and 0.00 for children. In some instances, parent's facial expression ($M = 0.04$), looking behavior ($M = 0.04$) and -one or multiple- limbs ($M = 0.02$) were not visible. Mostly, this was caused by using or taking objects. Adequate sight on the children's facial expression and looking behavior was more often blocked from the coder's view ($M = 0.11$ for both behaviors), mostly because of the parent's movements. However, based on the behavioral patterns of parents and children just before and shortly after an instance of inadequate visibility, the coders did not have the impression that

inadequate visibility of a behavior was in any way systematically linked to the (presumed) presence or absence of that specific behavior.

4.3. Suggestions for further research

First, intervention-oriented research is warranted offering concrete support to parents in stimulating interactive behaviors in their children. For example, an intervention study could be based on this study's conclusion that combining several social behaviors is more effective than showing singular behavior in evoking the child's looking behavior. Since object-oriented behaviors are rarely combined with socially-oriented behaviors, another intervention study could explore if combining these two types of behavioral clusters by parents can increase children's responsiveness to objects (or even their social responsiveness). Further research could also try to uncover why parents are not persistent in using objects within the interaction and their object-related behavior is not socially embedded. For example, it is possible that parents are influenced by previous experiences with their child and know/assume the child does not appreciate or respond to object-oriented behavior. It is also possible that parents don't feel competent choosing and manipulating 'developmentally appropriate' objects 'the right way', have few hopes for developmental benefits resulting from an object-oriented approach or just prioritize social stimulation and interaction.

As stated previously, behavioral frequencies as well as the strength and direction of behavioral linkages could be further explored on a more individual (dyad) level, by identifying whether different dyads are characterized by different behavioral patterns and whether these differences can be explained on the basis of certain parental or child characteristics (such as age, gender, etiology, sensory impairments or health issues). Further, we always conducted one-tailed *t*-tests to look for behavioral co-occurrences or temporal dependencies that were higher than expected by chance, identifying 'facilitating' behavior(s) that seem to 'predict' the presence of other behavior(s). A different approach could be to identify linkages that are lower than expected by chance and thus identify 'impeding' behavior(s) that 'predict' the absence of other behavior(s).

Acknowledgements

We would like to thank all participating families for their time, effort and enthusiasm. Also, we are immensely grateful to Ann Dhondt, Gertruud Schalen, Kristien Hermans, Lien Vanderkerken, Minou Nauta, Riëtte Krijgsheld and Stephy Colla for their contribution to the broader project in which this study is embedded. This work was supported by the Research Foundation in Flanders, Belgium [grant ZKC9876] and approved by the Social and Societal Ethics Committee (KU Leuven, Belgium).

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