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Exploratory behaviour and executive functions: A relationship that can be manipulated?

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ABSTRACT

This thesis examined the possibility of a relationship between exploratory behaviour and executive functions (i.e. cognitive development) in 137 children (76 boys and 61 girls (M_{pre} = 5.3 years; *SD* = .6; M_{post} = 6.3 years; *SD* = .6)). Additionally, the effect of an intervention, aimed at improving children's executive functioning, on their exploratory behaviour was examined using a pretest posttest intervention design. This question was tested on a sample of 247 children containing 137 boys and 110 girls (M_{pre} = 5.3 years; *SD* = .6; M_{post} = 6.3 years; *SD* = .6). Parents were randomly assigned to the intervention- or control group. Parents of forty children were trained on how to stimulate their children's social- and cognitive functioning, with a major focus on executive functioning, and parents of 207 children were not. Executive functions are known to be trainable and believed to be related to the development of exploratory behaviour. Playhouse, a newly developed task, assesses the quality of exploration. The executive functions; inhibition, working memory and attention, were measured with the Amsterdam Psychological Tasks. The results suggest that a relationship between children's executive functioning and their quality of exploratory behaviour exists. However, these relationships had a small effect. Additionally, it was found that children's executive functioning and quality of exploratory behaviour depend on their age. However, it remains unclear whether the improved executive functions with increasing age affect the increasing quality of exploratory behaviour with increasing age. Furthermore, the results in this study suggest that training parents to stimulate their children's social- and cognitive functioning, with a major focus on executive functioning does not affect their quality of exploratory behaviour. Further research in this area is necessary in order to get a more accurate understanding of the relationship between children's executive functioning and their explorative behaviour, and the psychometric properties of Playhouse.

Keywords: cognitive development, exploratory behaviour, executive functions, Amsterdam Neuropsychological Tasks (ANT), Playhouse

Introduction

As soon as babies are born, they begin to explore the new world around them. Using their senses they can explore new events, people and things. As their exploratory adventures continue and they discover more things, they become more knowledgeable about the world, which influences their cognitive development (Gibson, 1988). Some important cognitive processes involve the development of executive functions (Geurts & Huizinga, 2011). In view of these findings, this study believes that exploratory behaviour is related to the development of executive functions. Therefore, the present study will focus on the exploratory behaviour of children and its relationship to their executive functioning. In addition, this study will focus on the influence that parents have on the development of their children's executive functioning and exploratory behaviour, because of the assumption that parents play a vital role in the development of their children through scaffolding (Bruner, 1975).

Exploratory behaviour

In former studies it becomes apparent that different perspectives on exploratory behaviour exist. According to Gibson (1988), exploratory behaviour becomes apparent through playful behaviour, curiosity or reaction to strangeness. Berlyne (1966) believes that exploration is motivated by "a need to know". In addition, other researchers believe that curiosity and exploration are used in order to learn (e.g. Henderson & Moore, 1979; Lorenz, 1969 as cited in Henderson, Charlesworth & Gamradt, 1982). Furthermore, humans use their sensory- and action systems to gain knowledge from the environment (Gibson, 1988). Thus, in this study, exploratory behaviour is believed to be the action a person undertakes in order to gain information from the environment, motivated by a need to know. These actions can manifest themselves as playful behaviour, curiosity or reactions to strangeness.

Cognitive development

It is believed that exploratory behaviour is related to cognitive development. According to the cognitive theory of Piaget, schemas are used in order to explore and understand the world (Verhulst, 2008). Schemas are cognitive structures or mental representations that form as people explore their environment. They are considered to be the basic units of knowledge that children construct in order to adapt to their

environment. Piaget describes adaptation as the process in which children change their behaviour or thinking patterns (based on schemas) in order to function more efficiently. In the development of exploratory behaviour, adapting to one's environment can play a vital role. In order to stimulate this process of adaptation, two complementary processes influence the development of schemas. These processes are assimilation (using existing skills and knowledge in new situations) and accommodation (adjusting existing skills and knowledge to new situations) (Bernstein, Penner, Clarke-Stewart & Roy, 2006; Verhulst, 2008). The goal of these complementary processes is to maintain a balance between behaviour and the demands that the environment holds. This balance is called equilibrium, which indicates that self-regulated processes are present. Self-regulated processes are needed for optimal adaptation and cognitive development (development of e.g. thinking, language, attention and memory), which can play a vital role in the development of exploratory behaviour (Verhulst, 2008).

Executive functions

An important process involved in the cognitive development entails processing information from the environment, in which executive functions are involved (Geurts & Huizinga, 2011). Executive functions involve a wide range of (complex) cognitive processes, which are believed to be related to exploratory behaviour in this study. Executive functions are required cognitions to regulate one's own behaviour (Geurts & Huizinga, 2011; Verhulst, 2008). Moreover, these executive functions are processes that, in cooperation with each other, lead to goal oriented behaviour (Geurts & Huizinga, 2011; Monette, Bigras & Guay, 2011). Currently, many articles describe different cognitive processes being part of the executive functions. The most recognized cognitions that are defined as executive functions are inhibition (skill to stop or suppress behaviour) and working memory (cognitive processes making it possible to temporarily access information in order to perform mental tasks) (e.g. Calkins & Marcovitch, 2010; Diamond & Lee, 2011; Geurts & Huizinga, 2011; Pennington, Bennetto, McAleer & Roberts, 1996). Around twelve months of age these executive functions can be assessed and their profile becomes more distinguished at the ages of seven or eight (Case, Kurland & Goldberg, 1982; Dempster, 1993). Numerous studies show that these executive functions improve with age, each at a different pace (e.g. Bédard et al., 2002; Cepeda, Kramer & Gonzalez de Sather, 2001;

De Luca et al. 2003; Gathercole, Pickering, Ambridge & Wearing, 2004; Luna, Padmanabhan & O'Hearn, 2010). Children show less differences between ages in performance on inhibition tasks, after the age of eight (Bédard et al., 2002). Also, performance on working memory tasks improve significantly between the ages of four and fifteen (e.g. Gathercole, Pickering, Ambridge & Wearing, 2004; Luna Padmanabhan & O'Hearn, 2010).

Some researchers also include attention when describing executive functions (e.g. Alvarez & Emory, 2006; Anderson, Levin & Jacobs, 2002; Geurts & Huizinga, 2011). Attention consists of several processes that manage information that is picked up through the senses from the environment. In this study two kinds of attention are assessed: arousal and sustained attention. Arousal or alertness indicates that the brain is ready to receive information from the environment. Sustained attention is the ability to concentrate for a longer period of time. These attention processes become faster and more accurate with age. Also, the ability to concentrate increases (Geurts & Huizinga, 2011).

The previously mentioned executive functions operate together in order to process information from the environment (see Figure 1). According to the information processing theory (Verhulst, 2008), information is picked up through the senses. Before sending this information to the working memory (part of short term memory), attentional processes seek out relevant information. The working memory processes this information by withdrawing information (using schemas) from the long term memory. After working memory has processed the information, part of the information is stored in the long term memory (Verhulst, 2008). Information processing is also needed in order to attain certain goals, by which inhibiting certain inefficient behaviours plays an important role (Swaab & Noordam, 2012). This processing of information becomes faster and more efficient due to the utilization of more efficient strategies (based on schemas) and improved executive functioning that comes with age (Verhulst, 2008).

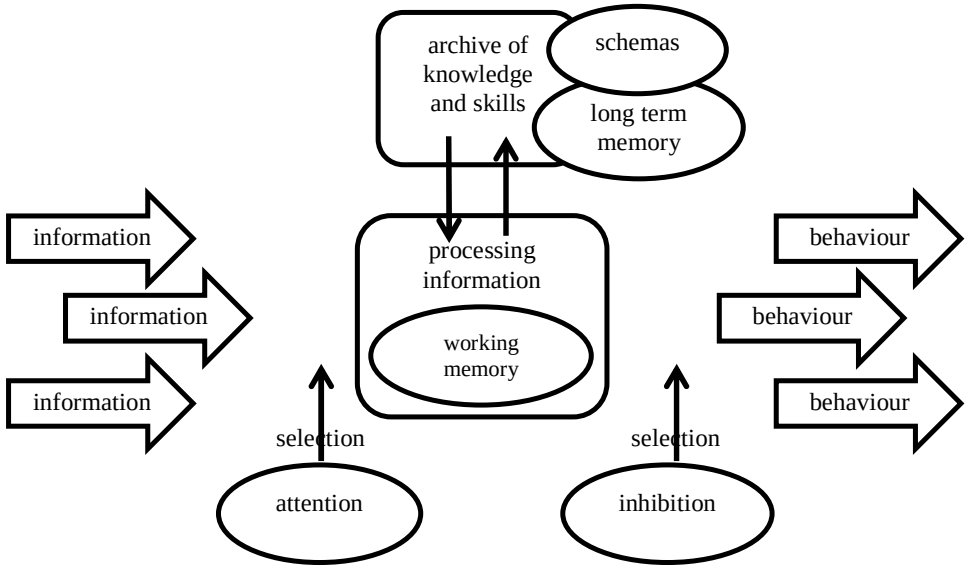

Figure 1. Processing information with Executive Functions in cognitive development (Swaab & Noordam, 2012).

Generally speaking, parents play a major role in their child's development through scaffolding. Scaffolding is the process by which parents support their children in novice situations (Bruner, 1975). In the research done by Hammond, Müller, Carpendale, Bibok & Liebermann-Finestone (2012), scaffolding had a direct effect on children's executive functioning a year later (age four). It was also found that scaffolding could indirectly affect children's executive functioning two years later (age four), depending on their verbal ability at age three. According to these findings, children's executive functioning can be stimulated through external resources. Other research supports this notion as well. For example, Diamond and Lee (2011) reviewed many interventions that addressed improving children's executive functioning. They concluded that children's executive functioning improved most through repeated training focused on their emotional-, social,- and physical development.

It is important to keep in mind that Gibson (1988) stated that exploration facilitates knowledge, which influences the cognitive development. According to Piaget's cognitive theory, schemas facilitate exploration through adaptation. Due to these findings, it is believed that exploratory behaviour and cognitive development are related. Executive functions are cognitions that are intertwined in the cognitive development. Therefore, it is believed that executive functions are related to exploratory behaviour, however an explicit link between these two aspects has to our

knowledge not yet been made in other studies. It is important to know which processes are involved in cognitive development and exploration and if they can be manipulated. Manipulation of these processes could lead to various ways of training and stimulating cognitive development. Numerous studies have already shown that executive functions can be trained, however its relationship with exploratory behaviour has not yet been studied. This thesis will investigate the relationship between exploration and executive functioning. As well as the possibility to influence exploratory behaviour through training parents to stimulate their child's social- and cognitive development, with a major focus on their executive functioning.

The present study

Considering the findings mentioned above, it is believed that a relationship between exploratory behaviour and executive functions exists. In order to investigate this relationship, the following research question will be examined: *Is there a relationship between exploratory behaviour and executive functions of children between four and eight years old?*

Exploratory behaviour is believed to be the action a person undertakes in order to gain information from the environment, motivated by a need to know. These actions can manifest themselves as playful behaviour, curiosity or reactions to strangeness. Furthermore, the following cognitions are defined as executive functions: inhibition, working memory and attention. Children between four and eight years old are chosen for this investigation, because children start attending school at the age of four in the Netherlands. Also, children's performance on executive functioning tasks improves rapidly before the age of eight. Thus, differences in task performance between measurements will be clearer.

Additionally, executive functions can be trained and it is believed that this affects exploratory behaviour. Thus, the next question examined is: *Does a parental training on stimulating their child's social- and cognitive functioning, with a major focus on executive functioning also affect the child's exploratory behaviour?*

Based on the theories and studies already mentioned, a relationship between children's exploratory behaviour and their executive functioning is expected. As well as the hypothesis, that training executive functions will affect exploratory behaviour. Another expectation of this study is that children's exploratory behaviour and executive functioning will improve with increasing age. Coupled with these

predictions, it is expected that children will improve in their exploratory behaviour over a one year period due to a parental training on stimulating their children's social- and cognitive development, with a major focus on their executive functioning.

Methods

Participants

The sample in this investigation was derived from a longitudinal Dutch government project called the Curious Minds Program, which focuses on the development of beta skills of primary school children. Participants in this program were selected on a voluntary bases from various schools in the province of South-Holland in the Netherlands (for specific towns, see appendix A). Participants had to meet the following criteria: 1. being between four and eight years old; 2. attending the school for at least two months; 3. speak Dutch; and 4. their parents had to be able to read Dutch. Parents were selected to participate in training sessions on how to stimulate their child's social- and cognitive functioning, with a major focus on executive functioning, based on how they rated their children on the Social Skills Rating System (SSRS; a parent-questionnaire that measures the social skills of their child). Parents of children with the 10% highest and lowest SSRS scores were randomly assigned to the intervention- or control group. The groups were matched on age and sex. The selection was based on the assumption that social skills are important for exploring the environment: better social skills help to create a stimulating learning environment, which will support the child's learning process.

There were originally 471 participants of which sixty parents received a training. Some participants dropped out between measurements due to moving house or changing their mind about participation. This study utilized two different sample sizes, one for answering each research question. Both samples are described below.

To determine whether a relationship between exploratory behaviour and executive functions exists, quality of $\text{exploration}_{\text{pretest-posttest}}$ and executive $\text{functions}_{\text{pretest-posttest}}$ of the control group were used in a correlational design. A sample size of 137 participants was used containing 76 boys and 61 girls. The mean $\text{age}_{\text{pretest}}$ was 5.3 years (*SD* = .6), ranging from 4.2 to 6.4 years old. Additionally, the mean $\text{age}_{\text{posttest}}$ was 6.3 years (*SD* = .6), ranging from 4.8 to 7.5 years old.

To determine if training parents to stimulate their children's social- and cognitive functioning, with a major focus on their executive functioning affects their

exploratory behaviour, data was examined in a pretest posttest intervention design. A sample size of 247 participants was used of which 137 were boys and 110 were girls. The mean $age_{pretest}$ was 5.3 years (*SD* = .6), ranging from 4.1 to 6.4 years old. The mean $age_{posttest}$ was 6.3 (*SD* = .6), ranging from 4.8 to 7.5 years old. Forty participants remained in the intervention group and 207 participants were included in the control group.

Instruments

Exploratory behaviour. This variable was measured using a new instrument called Playhouse. Playhouse was developed at the University of Leiden. It was a coloured touch screen (Ilyama ProLite T1930SR-1, 301.1 x 376.3 millimetres) that showed a playroom with toys and other objects. The objective of the task was that the participant explored the room for four minutes, by touching the different objects and discovering what happened. Before the game started, the participant was shown by the examiner how the touchscreen worked using three examples. The three examples showed a red ball, a red square and a rocket in consecutive order. These objects changed when touched; the ball turned green, the square became a green triangle and the rocket flew off. The first example of touching the screen, was demonstrated by the examiner. With the second and third example the examiner encouraged the participant to touch the screen. The validity and reliability of Playhouse are unknown to this date.

The basic display showed 32 objects. The objects that could be touched each represented a different level of exploration. Some objects showed no effect when touched (level 0; *N* = 16), while other objects revealed a hidden object, produced a sound or transformed (level 1; *N* = 16). Also, revealed objects (level 1) were able to reveal another object, produce a sound or transform when touched again (level 2; *N* = 8). Lastly, level three items (*N* = 4) could only be seen after level one and two were reached. These items produced a sound or transformed as well. In total there were 44 objects to be discovered.

In this study the *quality of the child's exploratory behaviour* was assessed. This variable was measured using the percentage of level three items discovered. The following formula was used to calculate this percentage: sum of clicks on all four level three items divided by the sum of clicks on all items excluding missed and persevered clicked items (continuance of clicking same item), multiplied by 100.

Participants showed more quality during exploration, when they discovered more objects, especially more level three objects, but did not get stuck on them.

Executive functions. These were measured using the Amsterdam's Neuropsychological Tasks (ANT; De Sonneville, 1989). This instrument was developed in order to evaluate the basic processes that underlie complex cognitive processes, like executive functions (De Sonneville, 1989). The ANT is a set of 38 computer based tasks that measure speed, stability and accuracy of response behaviour through auditory and visual processes. These parameters reflect the quality of executive functions of the subject. Studies showed that the ANT was valid and (test-retest) reliable (De Sonneville, 2005). In this study a selection of ANT-tasks was used to measure various executive functions, as described below.

Inhibition. Inhibition was measured with the Go-No Go task (GNG). During instruction, two objects were shown on the screen, the Go stimulus (square with an opening at the bottom) and the NoGo stimulus (square). The participant was instructed to press the button when the Go stimulus (75%) was shown and to wait until the next object appeared, when the NoGo stimulus (25%) was shown. The task took about four minutes. The participant received instructions through an example and had the opportunity to practice. The percentage of false alarms was recorded, indicating the amount of impulsive behaviour. Less impulsive behaviour signified more inhibited behaviour (De Sonneville, 2011).

Working memory. Working memory was measured with the Spatial Temporal Span task (STS). This task displayed a three by three matrix on the screen containing nine squares that had to be clicked in the correct order. This task had two parts. In the first part, participants had to click a series of squares in the exact order as the computer had done. In the second part, participants had to click the squares in the opposite order as indicated by the computer. In each trial more squares were added to the sequence, thus increasing difficulty. When too many mistakes were made, the computer stopped the task automatically. Each part started with instruction through an example and practice trials. Each part took about eight to ten minutes to complete. Working memory was measured by averaging the sum of the correctly identified squares clicked in the correct order in both test parts. A higher average of correctly clicked squares indicates a better working memory (De Sonneville, 2011).

Attention: arousal**.** Arousal was measured using the Baseline Speed task (BS). With this task the button had to be pressed as fast as possible when a cross on the

computer screen changed into a square. The task was executed twice (2 x 32 trials), using the finger of the non-dominant hand first, followed by the finger of the dominant hand to press the button. Before the task, the participant was instructed with an example and had the chance to practice. The average reaction time of both hands was recorded. A lower reaction time indicated that the subject was more alert (De Sonneville, 2011).

Attention: sustained attention. The Sustained Attention Objects 2 keys task (SAO2) was used to assess sustained attention. This task displayed on the screen a house with three windows and a door. The participant had to press the "yes" button, when the target animal appeared in one of the windows. When another animal appeared in one of the windows, the participant had to press the "no" button. This task also started with an example and practice trial. The task took about nine to twelve minutes to complete. There were twenty series to be completed. The average time to complete all series (overall tempo) was recorded. A faster overall tempo (shorter time to complete the series) indicates being able to sustain attention for a longer period of time (De Sonneville, 2011).

Procedure

In 2009, schools in the Netherlands were contacted by students to see whether they were interested in participating in the Curious Minds Program. If they were interested, a letter with information about the project was sent to them. Consent was asked from the parents through a letter. In 2009 (January through April) trained Master students tested all the participants. Playhouse and the ANT were part of a larger test battery that was implemented during three sessions of an hour with a fixed order of tasks on different days. The tasks were done at school in quiet testing areas. Before executing the tasks, the participants received clear instructions. After test completion, the participants were rewarded with a domino game. In the same year, a random sample of parents attended six sessions (two hours each) focused on how to stimulate their children's social- and cognitive functioning, with a major focus on their executive functioning (intervention group). Each session introduced a different theme and all parents received an instruction booklet with tasks they could practice with their child at home. The themes covered topics on exploration, executive functions, emotional perception and Theory of Mind. Approximately one year later, in 2010, posttest measurements were completed in the same manner as in 2009. This

exploratory study, including both a correlational design and pretest posttest intervention design, focused on pretest and posttest measures of exploratory behaviour and of executive functions of children.

Data-analysis

The analyses were executed in SPSS 20 (IBM SPSS Statistics 20 Student Version, 2011). Assumptions of normality, linearity and homoscedasticity were tested. Data was considered normal when the kurtosis and skewness lay between -2.5 and 2.5. Linearity and homoscedasticity were studied with scatterplots. If assumptions were not met, non-parametric tests and sample sizes were considered for interpretation purposes. Extreme outliers (quartile 1 – (3 x interquartile range) > values > quartile 3 + (3 x interquartile range); De Vocht, 2007) were removed if they had an impact on the assumptions (see "Results"). Participants with missing values for exploration, executive functioning, intervention and age were excluded.

To determine whether a relationship between exploratory behaviour and executive functions existed, a correlational design was applied. Correlational tests were applied to the following variables: quality of exploration$_{\text{pretest-posttest}}$, executive functions$_{\text{pretest-posttest}}$ (working memory, inhibition, arousal and sustained attention) and age$_{\text{pretest}}$ of the control group, using a Pearson correlation (r_p; normal distributions) and/ or Spearman correlation (r_s; non-parametric distributions). Effect sizes of these correlations were considered to be small (r = .100 - .242), medium (r = .243 - .370) or large (r > .371) (Cohen, 1988).

To examine whether the intervention affected exploratory behaviour, a pretest posttest intervention design was used, by applying a General Linear Model (GLM) procedure of a repeated measures analysis of variance. Quality of exploration$_{\text{pretest-posttest}}$ was the dependent variable, the within-subjects factor was Time (pretest and posttest) and the Intervention was the between-subjects factor (control group versus intervention group). Also, age$_{\text{pretest}}$ was added as a covariate in order to assess the influence of age on quality of exploration. The following effects were examined: 1. the main effect of the intervention, in order to establish whether or not a difference in the quality of exploration between the control- and intervention group exists; 2. the main effect of Time, to see whether or not participant's exploratory behaviour improves over a one year period; 3. the main effect of age$_{\text{pretest}}$, in order to establish whether or not exploratory behaviour is dependent on age, because of the assumption

that exploratory behaviour and executive functions improve with age; and 4. the interaction effect between Time and Intervention, in order to establish whether or not exploratory behaviour improves over a one year period due to the Intervention. Effect sizes of these main- and interactions effects were considered to be small (partial η^2 = .04), medium (partial η^2 = .25) or large (partial η^2 = .64) (Ferguson, 2009).

Results

Relationship between exploratory behaviour and executive functions

*Descriptive statistics***.** A detailed report of the descriptive statistics of quality of exploration and executive functions of the control group are depicted in Appendix B. All participants with any missing values were listwise deleted. This was done in order to maintain a large enough sample size with participants having complete data on both pretest and posttest. In addition, five extreme outliers were removed, further reducing the sample size to 137 participants. According to the skewness and kurtosis, only quality of exploratory behaviour$_{pretest}$ was not normally distributed.

Correlations: exploratory behaviour, executive functions and age. Significant correlations were found between the quality of exploration, executive functions and age (see Table 1). However, working memory did not show a significant correlation with exploratory behaviour. Also, a significant correlation between quality of exploration$_{pre}$ and quality of exploration$_{post}$ was not found in the control group.

Significant, but small, positive correlations were found between the quality of exploration$_{pretest}$ and the pretest measure of inhibition and the posttest measure of inhibition. These correlations suggest that participants with a higher quality of exploration show less inhibition, also a year later.

A significant and small negative correlation was found between the quality of exploration$_{pretest}$ and level of arousal$_{pretest}$. This correlation suggests that children showing a higher level of arousal (lower reaction time) have a higher quality of exploration.

Also, a significant small negative correlation was found between the quality of exploration and the pretest measures of sustained attention. This correlation shows that participants with a higher level of sustained attention (faster tempo overall of completing a task) show a higher quality of exploration.

A significant and small positive correlation was found between quality of exploration$_{pretest}$ and age. This correlation suggests that older participants have a higher quality of exploration.

Also, a significant and large positive correlation was found between age and working memory$_{pretest\text{-}posttest}$. These correlations show that older participants have a higher capacity of working memory, also a year later.

Significant, medium to large negative correlations were found between age and arousal$_{pretest\text{-}posttest}$ and sustained attention$_{pretest\text{-}posttest}$. These correlations suggest that older participants have a higher level of arousal and sustained attention, also a year later.

Table 1.

Correlations between children's Quality of Exploration and age and their Executive Functions.

		Quality of exploration		*Inhibition*		*Working memory*		*Arousal*		*Sustained attention*	
		pre	post	pre	post	pre	post	pre	post	pre	post
Quality of exploration	pre (r_s)	--	n.s.	.17*	.22**	n.s.	n.s.	-.20*	n.s.	-.24**	n.s.
	post (r_p)	n.s.	--	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Age	pre (r_p)	(r_s) .22**	n.s.	n.s.	n.s.	.46**	.45**	-.53**	-.37**	-.26**	-.31**

*(n.s. = not significant; * = significant at .01 level (2 tailed); ** = significant at .05 level (2 tailed))*

Intervention and exploratory behaviour

Descriptive statistics. Another sample was used to test the second research question. The details of the descriptive statistics of quality of exploration are reported in Appendix C. Participants with missing values for quality of exploration, intervention and age were removed, as well as six extreme outliers. This resulted in a sample size of 247 participants of which 40 participants were included in the intervention group (207 participants in control group). According to the skewness and kurtosis, only quality of exploration$_{pretest}$ was not normally distributed. However, analysis of variance is robust to moderate deviations of normality.

Main- and interaction effects: quality of exploration. Main- and interaction effects were examined with quality of exploration (pretest and posttest), Intervention (intervention versus control group) and Time (differences between pretest and posttest) with and without age as a covariate (see Table 2 and Table 3). No main effect was found for the intervention, with or without age as a covariate. This effect suggests that the control- and the intervention group did not differ significantly from each other in their quality of exploration.

A small main effect was found for Time, without age as a covariate. This result shows that children's quality of exploration increased significantly over a one year period, regardless of their intervention status. This main effect for Time disappeared when age was added as a covariate.

No interaction effect between Time and Intervention was found, with or without age as a covariate. These results suggest that changes in the children's quality of exploratory behaviour over a one-year period did not differ significantly between the intervention and the control group.

Table 2.

Means, standard deviations (SD) and partial η^2 of significant effects on Quality of Exploration without age as covariate.

		Mean	SD	p	Partial η^2
Main effects	*Intervention*				
	Control group	12.9	.6	n.s.	--
	Intervention group	9.9	1.4		
	Time				
	Pretest	10.1	1.1	.04	.02
	Posttest	12.7	.9		
Interaction effects	*Intervention x Time*				
	Control group				
	Pretest	11.4	.9	n.s.	--
	Posttest	14.4	.7		
	Intervention group				
	Pretest	8.8	2.0		
	Posttest	11.0	1.7		

Table 3.

Means, standard deviations (SD) and partial η^2 of significant effects on Quality of Exploration with age as covariate.

		Mean	SD	p	Partial η^2
Main effects	*Intervention*				
	Control group	12.9	.6	n.s.	--
	Intervention group	10.0	1.4		
	Time				
	Pretest	10.2	1.1	n.s.	--
	Posttest	12.8	.9		
	Age	5.3	.6	.01	.03
Interaction effects	*Intervention x Time*				
	Control group				
	Pretest	11.4	.9	n.s.	--
	Posttest	14.4	.7		
	Intervention group				
	Pretest	9.0	2.0		
	Posttest	11.1	1.7		

Conclusion and Discussion

This thesis explored the possibility whether a relationship between exploratory behaviour and executive functions exists. As well as the hypothesis that training parents to stimulate their children's social- and cognitive functioning with a major focus on their executive functioning, affects their exploratory behaviour. Two research questions addressed these hypotheses and are discussed in the following paragraphs.

Relationship between exploratory behaviour and executive functions

In order to explore whether or not a relationship exists between exploratory behaviour and executive functioning, the following research question was examined: *Is there a relationship between exploratory behaviour and executive functions of children between four and eight years old?* This study showed that children with a higher quality of exploration showed less inhibition, also a year later, and higher levels of arousal and sustained attention. These results support the hypothesis of a relationship between the quality of exploratory behaviour and the level of executive functioning in young children. These findings support the notion that more curious

and playful children gain more information and learn from their environment (e.g. Gibson, 1988; Henderson & Moore, 1979; Lorenz, 1969 as cited in Henderson, Charlesworth & Gamradt, 1982), which has to be processed in the brain. High levels of arousal indicate that the brain is ready to receive information from the environment through the senses and a high level of sustained attention allows for the ability to concentrate for a longer period of time (Geurts & Huizinga, 2011). Both attentional processes seek out relevant information to be processed in the brain (Verhulst, 2008), which enables quality of exploratory behaviour. When more information has to be processed, the brain might have more trouble inhibiting behaviour, and this might also result in getting more easily distracted from certain goals (Swaab & Noordam, 2012). These distractions, could however, also lead to more discoveries, thus gaining information from the world, which is an important goal of exploratory behaviour. It remains unclear what the optimal balance between exploratory behaviour, level of inhibition and attentional processes is to create the opportunity for optimal adaptation and cognitive development (Verhulst, 2008), which could lead to optimal learning strategies. The effect sizes of these relationships were in this study, however, small. Future research needs to address the relationship between children's executive functioning and their quality of exploratory behaviour, in order to get a more accurate understanding of the nature of the relationship and which processes are involved.

Also, no relationships were found between the quality of exploratory behaviour and the capacity level of working memory. As well as that no relationship was found between the pretest and posttest measurements of quality of exploratory behaviour. In previous studies, it was found that executive functions (e.g. working memory), can be assessed around twelve months of age and form a distinguished profile at the ages of seven or eight (Case, Kurland & Goldberg, 1982; Dempster, 1993). With this in mind, it could be assumed that the children's working memory in this study (ages four to eight) was developed to such an extent that it could be efficiently utilized in processing information. The amount of working memory needed to perform the Playhouse task might have been quite minimal, resulting in a lack of association. The exploration tasks might not have been challenging enough for the working memory. In upcoming research on this aspect, it is advised to further analyse and adjust the exploration task in order to make them challenging enough for children, so that the level of children's optimal performance in relation to their working memory can be better established. Also, no relationship was found between the pretest

and posttest measures of children's quality of exploration. This outcome might be explained by the children's task approach not being consistent, or by the design of the task, as children were asked to explore without any preset goal(s), which might have increased more random behaviour. However, in the second part of this study, using both the control and the intervention group, a significant increase in the level of exploratory behaviour between pre- and posttest was found. So, sample bias also partially explains this finding. For future research in which Playhouse will be used, it is important to determine the validity and reliability of this instrument to be certain that all aspects of quality of exploration are measured accurately.

Furthermore, this study showed that older children have a higher level of quality of exploration, a higher capacity of working memory, and higher levels of arousal and sustained attention. These relationships were also found a year later. These results support the hypotheses that children's quality of exploratory behaviour and executive functioning depend on their age. The effect sizes of these relationships were small, medium or large. No relationships were found between children's age and their level of inhibition. These results support the notion that children's executive functioning improves with age (e.g. Bédard et al., 2002; Cepeda, Kramer & Gonzalez de Sather, 2001; De Luca et al. 2003; Gathercole, Pickering, Ambridge & Wearing, 2004; Geurts & Huizinga, 2011; Luna, Padmanabhan & O'Hearn, 2010). However, it remains unclear whether the improved executive functions with increasing age affect the increasing quality of exploration with increasing age. Further research in this area is needed in order to get a more accurate understanding of the relationships between children's executive functioning, quality of exploration and their age.

As previously mentioned, no relationship was found between children's level of inhibition and their age. As well as working memory, according to previous studies, children's level of inhibition can be assessed around twelve months of age and form a distinguished profile at the ages of seven or eight (Case, Kurland & Goldberg, 1982; Dempster, 1993). With these findings, it could be assumed that children's level of inhibition in this study (ages four to eight) was developed sufficient enough in their processing of information, such that within the relatively small age range in this study no age differences in the level of inhibition could be detected.

To summarize, the results suggest a relationship between children's quality of exploratory behaviour and some aspects of executive functioning exists. However, these relationships had a small effect. In addition, it was found that children's quality

of exploratory behaviour and their level of executive functioning, are age depended, except for level of inhibition. In this study it remains unclear, however, whether improved executive functions with increasing age affect the increasing quality of exploratory behaviour with increasing age. It is important to do more research in this area in order to get a more accurate understanding of the relationships between children's executive functioning and their quality of exploratory behaviour and how these affect their learning.

Intervention and exploratory behaviour

The second research question, using a larger sample of children, explored the hypothesis that training parents to stimulate their child's social- and cognitive development, with a major focus on executive functioning, might affect their exploratory behaviour. It was found that children's quality of exploration increased over a one year period, regardless of their intervention status. This was different from the analysis of association in the control group, which showed no significant pre- and posttest correlation for exploratory behaviour. This might suggest a possible sample bias. It was also found that children's quality of exploration was dependent on their age. A difference in the quality of exploration between the control- and intervention group was not found. These results support the hypothesis that children's quality of exploration increases with age. However, they do not support the hypothesis that the study's training affects the quality of exploration of young children over a one year period. It remains unclear whether children's increase in exploratory behaviour with increasing age, is due to improved executive functioning with increasing age (e.g. Bédard et al., 2002; Cepeda, Kramer & Gonzalez de Sather, 2001; De Luca et al. 2003; Gathercole, Pickering, Ambridge & Wearing, 2004; Luna, Padmanabhan & O'Hearn, 2010). In addition, according to the research done by Diamond and Lee (2011), executive functions could improve most through repeated training focused on the emotional-, social and physical development of children. However, this study's training did not seem to affect exploratory behaviour. The current training was not specifically developed to stimulate children's exploratory behaviour only, as many more subjects were taught. This could have made it more difficult to detect an intervention effect. Also, other studies (e.g. Diamond & Lee, 2011) trained children's executive functioning directly, instead of training their parents to stimulate their children's executive functioning. This study did not assess how much the parents

practiced at home with their children, what they were taught. As well as what the quality of their interaction with their child was. Future research needs to address these aspects in order to gain a clear understanding of the relationship between children's executive functioning and their exploratory behaviour. As well as the affect this parental training has on children's executive functioning. The task to measure exploration, Playhouse, might also be too limited to assess different aspects of exploration and might also have limited external validity. More research is needed to better understand the psychometric properties of this assessment tool for exploratory behaviour.

To summarize, it remains unclear whether children's increasing quality of exploration with increasing age, is due to improved executive functioning with increasing age. In addition, the results in this study suggest that training children's executive functioning does not affect their exploratory behaviour. It is important to do more research in this area to get a more accurate understanding of these aspects.

Strengths and limitations of this study

Strengths. This is one of the first studies to research exploratory behaviour in young children in relationship to their executive functioning. It consisted of a sufficient sample size and sufficient pretest posttest intervention design with random assignment to intervention conditions. To assess executive functioning, standardized and psychometrically sound tasks were used

Limitations. The validity and reliability of the instrument Playhouse is unknown, due to its fairly new development. Therefore the construct and content validity are unknown and an uncertainty exists whether the instrument measures of the quality of exploration are sufficient. It is important to assess measures of validity and reliability for Playhouse in the near future, in order to know how well it measures different aspects of exploration. Furthermore, the nature of how children's exploration and executive functioning were assessed might have had a negative impact on the results. Both instruments required a certain clicking or touching behaviour, which might lead to similar results. Therefore, it is important to add other types of instruments to the study of exploratory behaviour and executive functioning. In addition, the impact of the parental training on the children's level of executive functioning was unknown. The training was not specifically designed to only train executive functioning and or exploratory behaviour; it also addressed emotion

recognition, social cognition, and planning. Also, uncertainty exists whether parents actually followed through with practicing with their children at home. Also, it is unknown what the quality of the parent-child interaction is. These are important aspects to study in future research.

This exploratory study shed some light on the processes involved in the development of executive functions, changes in explorative behaviour and the effect of a parental intervention on exploratory behaviour. More research is needed in this area to improve the assessment of exploratory behaviour and to get a more accurate understanding of what processes are involved in the cognitive development and how these can be manipulated in order to improve children's cognitive development.

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Appendix A

Towns of schools involved in study.

1. Capelle aan den IJssel
2. Delft
3. Den Haag
4. Katwijk aan Zee
5. Leiderdorp
6. Leidschendam
7. Naaldwijk
8. Noordwijk
9. Oegstgeest
10. Rhoon
11. Rotterdam
12. Sassenheim
13. ‘s Gravenzande
14. Wateringseveld
15. Zoetermeer
16. Zwijndrecht

Appendix B

Descriptive statistics: quality of exploration$_{pretest\text{-}posttest}$ and executive functions$_{pretest\text{-}posttest}$ of control group.

		Attribute/ task	Mean	Standard deviation	Minimum	Maximum	Skewness	Kurtosis
Pre-test measurements		Quality of exploration	9.9	11.4	0	62.5	1.8	4.5
	Executive functions	Inhibition	33.3	22.3	0	100.0	1.1	1.0
		Working memory	13.5	9.8	.5	43.0	1.0	.4
		Arousal	633.0	176.8	347.0	1183.0	1.0	.7
		Sustained attention	16.0	3.2	8.5	27.5	.7	.8
Post-test measurements		Quality of exploration	13.7	10.0	0	43.5	.8	.4
	Executive functions	Inhibition	21.5	14.0	0	66.7	1.0	1.0
		Working memory	24.1	10.6	3.0	52.0	.4	-.3
		Arousal	540.4	125.7	341.0	1013.0	1.1	1.2
		Sustained attention	13.2	2.7	7.9	21.4	.7	.2

Appendix C

Descriptive statistics: quality of exploration$_{pretest\text{-}posttest}$.

Attribute	Mean	Standard deviation	Minimum	Maximum	Skewness	Kurtosis
$Quality_{pre}$	11.0	12.5	0	62.5	1.7	3.3
$Quality_{post}$	13.9	10.7	0	51.1	1.0	.8