Cognition 145 (2015) 1–12

Contents lists available at ScienceDirect

Cognition

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

The development of the illusion of control and sense of agency in 7- to-12-year old children and adults

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ARTICLE INFO

Article history:
Received 2 December 2014
Revised 7 August 2015
Accepted 10 August 2015

We would like to dedicate this paper to Joop van der Pligt (1951–2015), as the research it describes reflects the outcomes of his passionate research interest in the illusion of control.

Keywords:
Illusion of control
Sense of agency
Positive illusions
Magical thinking
Children
Development
Self-attribution bias

ABSTRACT

The illusion of control can be defined as the erroneous belief that one's actions cause a specific outcome, whereas sense of agency refers to the subjective feeling of authorship over one's actions. In the present study we investigated the development of illusory control and sense of agency. A novel card-guessing game was developed in which 7- to-12-year old children (Study 1) and adults (Study 2) were required to select a card, and we manipulated the congruence of the outcome with their initial choice (i.e. congruent or incongruent) and the valence of the outcome that was presented (i.e. positive or negative). We found that illusory control and the self-attribution bias (i.e. the bias to attribute positive outcomes to oneself) in the card guessing game decreased, as children get older. In contrast, for both children and adults sense of agency in the task was similarly affected by outcome congruency, suggesting that the ability to relate predicted to observed action outcomes reflects a basic mechanism that helps people to sustain a sense of agency. Thus, while the illusion of control decreases as we get older, the experience of agency as a function of outcome congruency seems to be more stable across development.

1. Introduction

Imagine a seven-year-old boy playing a dice-throwing game. Before throwing he carefully blows the dice in the hope that this will affect the outcome. This is an example of the *illusion of control*; i.e., the erroneous belief that one's actions can cause a certain outcome, even if that outcome is in fact uncontrollable and entirely determined by chance (Langer, 1975). Now imagine a seven-year-old boy who receives a computer racing game for his birthday. After starting the game, the boy may be engaged in driving the car and steering the remote control wheel. As long as the movements displayed on the screen are congruent with the boy's movements, he will experience a strong *sense of agency*, i.e. the belief that one is controlling one's own actions and their outcomes in the world (Wegner, 2003). However, when the movements made by the car do not match the movements made via the remote control wheel (e.g. when the computer is in demo mode), this will result in a reduction of sense of agency.

In this paper we draw parallels between research on the illusion of control and research on sense of agency – two related concepts that have, surprisingly, to a large extent been discussed separately throughout the literature. We will argue that the illusion of control is strongly related to a process of reinforcement learning and the detection of illusory contingencies (for review, see: van Elk, Friston, & Bekkering, 2015). In contrast, sense of agency is primarily related to a predictive process, in which the anticipated outcomes of one's actions are compared with the observed sensory consequences. We present two studies to investigate the development of the illusion of control and sense of agency in young children and adults.

1.1. Illusion of control

Early work on the illusion of control has shown that many people act as if they have control over situations that are actually determined by chance (Langer, 1975; Langer & Roth, 1975). For instance, people indicate having greater control over throwing dice or selecting a lottery ticket when performing the action themselves than if someone else does it for them (Langer, 1975). Based on these findings it has been suggested that the illusion of control is

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http://dx.doi.org/10.1016/j.cognition.2015.08.004
0010-0277/

especially likely to occur when a game of chance is approached as if it were a game of skill; i.e., when people erroneously attribute potential outcomes to one's abilities rather than to external factors or luck (Langer, 1975; Langer & Roth, 1975; Wohl & Enzle, 2002). Other studies have suggested that the illusion of control is caused by a process of associative or reinforcement learning, in which one's action is accidentally paired with a specific outcome (Blanco & Matute, 2015; Matute, 1996; Matute & Blanco, 2014). For instance, by using a random reinforcement schedule (i.e. sounds or lights were presented at random intervals) it was found that many participants developed a particular strategy for responding (e.g., pressing computer buttons in a specific order), and also reported feelings of control over the outcome (Blanco & Matute, 2015; Matute, 1996; Matute & Blanco, 2014).

Developmental studies have shown that the illusion of control is especially prevalent in young children and decreases with increased age (Heckhausen & Schulz, 1995; Weisz, 1980, 1981; Weisz, Yeates, Robertson, & Beckham, 1982). For instance, when kindergartners were presented with a game of chance (i.e. drawing cards blindly from a shuffled deck), they perceived outcomes as contingent upon competence-related factors (e.g. skills, age, etc.) whereas older children showed an awareness of the non-contingent nature of the game (Weisz, 1980). It has been suggested that this tendency of young children to over-estimate the amount of control that can be exerted over the environment is especially adaptive during early development (Heckhausen & Schulz, 1995). Young children are continuously faced with changes in their bodily and cognitive capacities and need to learn which aspects of their environment they can control, and which are beyond their control. An underestimation of the amount of control that can be exerted is likely to lead to passivity and learned helplessness (Rholes, Blackwell, Jordan, & Walters, 1980). In contrast, an overestimation of control may be adaptive because it helps the person to not miss opportunities to exert control (Haselton & Nettle, 2006; Haselton et al., 2009), as well as through its positive effects on self-esteem (Taylor & Brown, 1988).

The illusion of control may be considered a specific instance of 'magical thinking', which refers to a broader phenomenon where people tend to infer causal relationships (either real or illusory) between specific events in the world (e.g. as observed in belief in the laws of contagion and similarity in sympathetic magic; cf. Eckblad & Chapman, 1983; Nemeroff & Rozin, 2000). Illusory control is at the heart of different forms of magical thinking that involve personal action, such as the belief in sympathetic magic (e.g. belief in Voodoo, whereby a specific action is believed to have a distant effect; cf. Nemeroff & Rozin, 2000), and various superstitious beliefs and behaviors (Foster & Kokko, 2009). In line with the observed decline in illusory control with increased age, developmental studies on magical thinking have shown that younger children are more prone to magical thinking (i.e., perceiving illusory contingencies between two unrelated events), and are also more likely to accept magical explanations for anomalous events than older children (Rosengren & Hickling, 1994; Rosengren, Kalish, Hickling, & Gelman, 1994; Subbotsky, 2004). For instance, 4-year old children found it more difficult to distinguish between possible and impossible events than 5-year old children and they were more likely to give magical explanations, whereas older children explained anomalous events in terms of 'tricks' (Rosengren & Hickling, 1994; Rosengren et al., 1994).

The decline in magical thinking with increased age is typically interpreted as reflecting a transition from a cognitive processing style that is characterized by 'pre-causal explanations' (e.g. animistic or artificialistic), to causal or physical explanations (Laurendeau & Pinard, 1962; Rosengren et al., 1994). It is suggested that younger children do not yet have a model enabling them to distinguish what can be explained in terms of everyday causal principles and what not (Woolley, 2000). Piaget already noted that throughout development children have to learn when causal efficacy can be attributed to the self or to external factors (Piaget, 1960). Younger children may have specific difficulties with distinguishing non-contingent (e.g. chance) from contingent (e.g. skills) events (Weisz, 1980, 1981; Weisz et al., 1982). Interestingly, it has also been pointed out that magical and natural explanations for events may actually co-exist throughout development (Legare, Evans, Rosengren, & Harris, 2012), as children may be particularly motivated by a need for discovery, seeking and providing explanations for events that are novel or unexpected (Legare, 2015).

1.2. Sense of agency and the illusion of control

Whereas illusory control reflects a motivated tendency to believe that outcomes that are in fact determined by chance can be controlled (i.e. either by oneself, or through a process of vicarious control; Rothbaum, Weisz, & Snyder, 1982), 'sense of agency' refers to the basic feeling of authorship over specific actions and outcomes. In many cases illusory control and sense of agency are strongly related (e.g. in a game of chance one may develop a strong illusion of control and an accompanying strong sense of agency), but both concepts can also be disentangled. For instance, when driving a car in a computer racing game sense of agency may be quite high, while there is no illusory control (as the depicted car is in fact controlled by the driver).

A large number of studies have investigated the functional and neural mechanisms underlying sense of agency (for review, see: David, Newen, & Vogeley, 2008; de Vignemont & Fourneret, 2004; Kuhn, Brass, & Haggard, 2012), for instance by using experimental manipulations in which the congruency between intended and observed action consequences is systematically manipulated by introducing visuo-spatial or temporal deviations (Fourneret & Jeannerod, 1998; Franck et al., 2001; van den Bos & Jeannerod, 2002). Small deviations between performed and observed movements often remain unnoticed (e.g. Fourneret & Jeannerod, 1998), but with an increased mismatch between intended and observed action outcomes, sense of agency typically decreases and participants are more likely to attribute the observed movements to an external source (Fourneret & Jeannerod, 1998; Franck et al., 2001; van den Bos & Jeannerod, 2002).

An important model to account for these findings proposes that sense of agency depends on the successful integration of predicted and observed action effects, by using an internal forward model (Frith, 2012; however, for alternative theoretical models, see: Metcalfe, Eich, & Castel, 2010). Internal forward models of motor control propose that efferent signals from motor-related areas are used to anticipate the sensory consequences of one's movements (Wolpert, 1997). A mismatch between predicted and observed outcomes results in a 'prediction error signal' and a subsequent updating of one's forward model, resulting in the attribution of an outcome to an external cause for instance.

With respect to the development of sense of agency, several studies have shown that young children are characterized by a reduced awareness about the extent to which specific actions and outcomes can be controlled. For instance, pre-school aged children tend to confuse intended with accidental outcomes (cf. Metcalfe et al., 2010; Shultz & Wells, 1985; Shultz, Wells, & Sarda, 1980) and they tend to change their retrospective awareness and verbal reporting of their prior intentions based on the outcome of an action (e.g. 'Did you intend to hit the green or the red ball?'; cf. Astington, 2001; Phillips, Baron-Cohen, & Rutter, 1998; Shultz & Wells, 1985). In contrast, 5-year old children are well aware of the distinction between intentional and accidental actions and their outcomes (Lang & Perner, 2002; Shultz et al., 1980). Two recent studies that more directly assessed sense of agency in 10-year old children (Cavazzana, Begliomini, & Bisiacchi, 2014) and 8-to 10-year old children (Metcalfe et al., 2010), provided mixed findings. By using an implicit measure of agency detection (i.e. the so-called temporal binding paradigm), it was found that 10-year old children displayed a reduced temporal attraction between their actions and the sensory consequences of that action, suggesting an altered sense of agency in children (Cavazzana et al., 2014). In another study, it was found that metacognitive awareness of agency differs between 8–10 year old children and adults: whereas adults in general tended to underestimate their actual performance, children systematically overestimated their performance in a computerized task. Interestingly, though, it was found that the agency ratings for both adults and children were similarly affected by the congruence between performed and observed outcomes, e.g. when a temporal delay or spatial deviation was introduced.

In addition to being affected by the *congruency* of the outcomes, an important factor determining perceived control is the *valence* of the outcome. In general people tend to take credit for positive outcomes, whereas negative outcomes are more readily attributed to external factors, a phenomenon which is known as the self-attribution bias (Miller & Ross, 1975). Developmental studies have shown that the self-attribution bias decreases with age. It has for instance been found that 8–10 year old children tend to take more credit for positive outcomes that were actually generated by the computer than older participants (Metcalfe et al., 2010). Similarly, it has been found that young children tend to say that an outcome was intended when it satisfies a desire they have (Astington, 2001). Thus, in addition to being a predictive process, related to integrating predicted and observed outcomes, sense of agency can also be considered a retroactive process, whereby information regarding the valence of an outcome or contextual effects can affect feelings of agency (Aarts, Custers, & Wegner, 2005; Wegner, 2003; Wegner, Sparrow, & Winerman, 2004).

1.3. The present research

As described above, previous studies have shown that (1) young children are characterized as displaying an overestimation of the amount of control that can be exerted (i.e., illusory control), (2) young children seem to be characterized by an altered sense of agency compared to adults and (3) young children show a stronger self-attribution bias compared to older children and adults. The aim of the present study was to integrate and extend these findings on the illusion of control, sense of agency and the self-attribution bias. More specifically, the present study extends previous findings beyond what is currently known in at least three ways.

First, previous studies on the development of sense of agency have compared the performance of 10-year old children with adults (Cavazzana et al., 2014; Metcalfe et al., 2010). In contrast, in the present study we had the unique opportunity to test a large sample of 7- to 12-year old children, thereby allowing a more fine-grained analysis of the development of the illusion of control and sense of agency in children of different age groups. Second, previous studies on the illusion of control in children have relied on experimental paradigms in which the outcomes across the entire task were non-contingent upon actions of the participants; in these cases perceived control was indeed entirely illusory (e.g. Weisz, 1980, 1981; Weisz et al., 1982). However, when presented with a series of trials each individual outcome is likely to be perceived as congruent or incongruent with respect to one's intended outcome. For instance, when blowing the number 'six' on a dice, a subsequent throw resulting in 'six' would be congruent with one's expectations, whereas a 'five' would be incongruent. In the present study we investigated developmental trends in both the overall feeling of control across a chance game, as well as the dynamics of sense of agency over the course of the experiment (e.g. by focusing on the trial-by-trial effects of outcome congruency). Third, by independently manipulating two different factors affecting sense of agency (i.e. congruency and valence of the outcome), we were able to investigate whether sense of agency is similarly affected by outcome congruency in younger compared to older children. Furthermore, by manipulating the valence of the outcomes, it could be investigated to what extent this mechanism is related to and/or affected by other basic cognitive biases (e.g. the self-attribution bias).

We used a novel behavioral paradigm that was inspired by research on agency perception (Aarts, Custers, & Marien, 2009; Aarts et al., 2005; van der Weiden, Ruys, & Aarts, 2013), adapting the paradigm to make it more attractive for a younger population as well. In the current studies, 7- to 12-year old children (Study 1) and a group of adults (Study 2) played a computerized card guessing game in which they were required to select a face-down card from a deck of two rapidly flashing cards on a computer screen (see Fig. 1). Following their selection of a card, a randomized outcome was presented and participants were required to indicate to what extent they believed the card was selected by themselves or by the computer. The analysis focused on perceived control throughout the card guessing game as a measure of 'illusory control' and on perceived control as a function of action outcome, as a measure of the 'sense of agency'.

In addition to the behavioral task, we also included the magical thinking questionnaire (Bolton, Dearsley, Madronal-Luque, & Baron-Cohen, 2002), which measures the tendency to believe that specific thoughts or actions can have an effect on objectively unrelated events (e.g., whether thinking about sunny weather can make the sun appear). Furthermore, a locus of control scale for children was included (Nowicki & Strickland, 1971), as developmental changes in illusory control may be accompanied by changes in the perceived locus of control (internal vs. external) as well (e.g. Fluke, Webster, & Saucier, 2014). For instance, in recent work it was found that an external locus of control is associated with increased levels of superstition (Fluke et al., 2014). An external locus of control may enhance magical thinking, as belief in magic provides a mechanism to restore one's subjective feelings of control by deriving compensatory control from an external source, such as a deity, fate or karma (Kay, Gaucher, McGregor, & Nash, 2010).

Below we describe the main hypotheses of Study 1. First, we expected the illusion of control to decrease with age (Weisz, 1980, 1981; Weisz et al., 1982): that is, we hypothesized that across the entire experiment younger compared to older children would report higher overall subjective feelings of control. Second, we hypothesized that younger compared to older children would display a reduced effect of outcome congruency on perceived control – in line with the finding that younger children tend to confuse intended with accidental outcomes (cf. Metcalfe et al., 2010; Shultz & Wells, 1985; Shultz et al., 1980). Alternatively, if a basic agency mechanism to detect the congruency between intended and observed action outcomes is already in place from an early age onwards (Metcalfe et al., 2010), we should expect a similar effect of outcome congruency for both younger and older children. Third, we expected to observe a self-attribution bias reflected in higher control ratings for positive compared to negative outcomes. This bias was expected to be stronger for younger compared to older children (Mezulis, Abramson, Hyde, & Hankin, 2004). With respect to the questionnaire data: we expected that with increased age self-reported magical thinking should decrease (see also: Bolton et al., 2002), and locus of control should become more internal (Findley & Cooper, 1983; Nowicki & Strickland, 1971). Finally, we hypothesized that if the judgmental (i.e. perceived valence and control in the card guessing game) and questionnaire

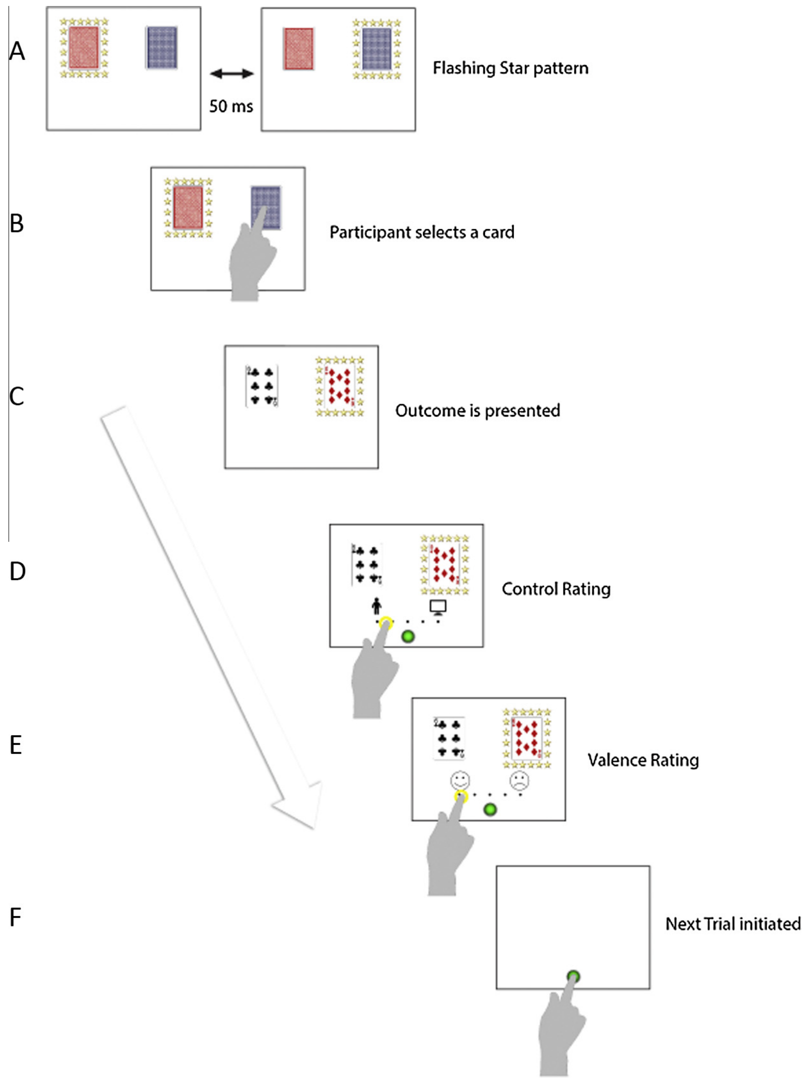

Fig. 1. Overview of the experimental procedure of the card guessing game. Children were presented with two blind cards surrounded by a rapidly alternating flashing star pattern (A). Children were required to select a card by pressing the touch screen (B). Next, the cards turned and the scores of both cards were presented and the card that was selected was marked by the star pattern. (C) Children were required to indicate perceived control (D) and perceived valence of the outcome (E) before starting the next trial (F).

measures reflect related theoretical constructs (i.e., illusory control), then these measures should be correlated.

2. Study 1: the illusion of control in children

2.1. Methods

2.1.1. Participants

Data from 133 children were included in the analyses (70 boys); their mean age was 9.2 years (*SD* = 1.7 years; range from 7 to 12). Prior to analysis, the data from ten children were excluded because of parents or siblings interfering with the task, more specifically, sitting next to or standing behind the child during the task ($n = 8$). In addition, data of two children were excluded due to language problems resulting in difficulties with understanding the task ($n = 2$).[1]

[1] Inclusion of the data from the excluded children in the analysis slightly changed the pattern of results: The correlation between age and the magical thinking and locus of control questionnaire was no longer significant, but the relation between age and the overall feeling of control and valence ratings persisted. In addition, we now observe an interaction between Age and Congruency, $F(5,135) = 2.3$, $p < .05$, $\eta^2 = .08$ for the control ratings in the card guessing game. With regard to the valence ratings, no significant interaction with Age was observed ($F < 1.6$, n.s.).

2.1.2. Experimental setup

As stimuli we used 40 pictures of playing cards (284 × 390 pixels) that ranged in value from 2 to 10 (aces were excluded). At the beginning of each trial two face-down cards (one red and one blue) were presented and a star pattern (435 × 536 pixels) rapidly alternated between the left and the right hand card every 50 ms (see Fig. 1A). The initial position of red and blue cards on the screen was randomized across trials, with the constraint that over the entire experiment blue cards appeared equally often on the left and the right side. The star pattern alternated until a touch screen response within the predefined area of the playing cards was detected and the response (*x* and *y* coordinates and response time) was stored for offline analysis (see Fig. 1B). In this way we obtained a measure of which card the participant intended to turn during that trial (i.e., the *intended* card).

Next, two playing cards were randomly selected by the computer from the set of 36 cards, with the only rule that both cards could not have the same value. In each new trial the set of cards was reshuffled and the first two cards were selected, thus resulting in a random selection of cards that was displayed to each participant. One of the cards was surrounded by the star pattern, which was defined as the *selected* card (see Fig. 1C). The position of the selected card marked with the star pattern was randomized across trials with the constraint that over the entire experiment the star pattern appeared equally often on the left and the right side. As a consequence of the random card selection, in some of the trials the *selected* card would be congruent with the *intended* card by the participants, whereas in other trials the selected card would be incongruent. Furthermore, in some of the trials the selected card would have a *lower value* compared to the not selected card and in other trials the selected card would have a *higher value*. *Congruence* of the selected and intended card (i.e. congruent vs. incongruent) and the *valence* of the selected versus the unselected card (higher value vs. lower value) were our main experimental manipulations.

To summarize the computerized card selection procedure, we provide a systematic overview of the different choices that were made:

(1) A red and a blue face-down card were first randomly presented in a left–right position (red–blue; 12 trials) or a right–left position (blue–red; 12 trials).
(2) On each trial, two face-up cards were randomly selected from the set of 36 cards, thus resulting in two cards of a type and value that was random from trial to trial.
(3) The star pattern that was presented randomly surrounded the left card in 50% of the trials (12 trials) and the right card in 50% of the trials (12 trials).

After a 500 ms interval, a visual analog scale was presented (713×416 pixels) representing a pictogram of the child on one side and the computer on the other side with five dots in between (Fig. 1D). A yellow circle could be positioned to indicate whether the child believed the selected card had been controlled by herself or by the computer (i.e. 'perceived control') and the answer could be confirmed by pressing the green button. Next, after 500 ms a visual analog scale was presented (713×416 pixels) representing a pictogram of a happy face on one side and a sad face on the other side with five dots in between (Fig. 1D). A yellow circle could be positioned to indicate whether the child was happy or unhappy with the outcome of the selected card (i.e. 'valence rating'; Fig. 1E). The *x*- and *y*-coordinates of the positioning of the circle and the response times for both the control-question and the valence-question were stored for offline analysis. After a 500 ms interval the next trial could be initiated by pressing the green button.

All stimuli were presented against a white background and at a screen resolution of 1920×1080 pixels. The experiment was controlled using Presentation software (Neurobehavioral systems, Albany, USA), running on a desktop PC (HP 7800, Intel CPU (2 cores), 2 GB RAM, Microsoft Windows 7). The experimental code that was used to run the present study is available upon request from the corresponding author.

2.1.3. Experimental procedure

The experiment was conducted at Science Live, Nemo Science Center (Amsterdam, the Netherlands). Visitors of this science museum were offered the possibility to participate in an experiment. Inside the museum a separate experimental room was available, in which two participants could be tested at the same time.

Before the start of the experiment, parents and their children were welcomed, and received a short instruction regarding the experimental procedure. Parents were asked to fill in an informed consent form to give approval for the participation of their child in the experiment. This procedure was approved by the ethics committee of the University of Amsterdam and followed the guidelines for research with children as specified by the Nemo Science Center. Parents were asked to stay in the pre-entrance of the experimental room, which was separated from the experimental room by glass doors through which the child could be observed. The experimenter invited the child to participate in the experiment.

At the beginning of the experiment, children were required to fill in two questionnaires (the magical thinking questionnaire; cf. Bolton et al., 2002; and a modified version of the children locus of control scale; cf. Nowicki & Strickland, 1971). The magical thinking questionnaire (MTQ) consisted of two subscales of ten items each, measuring belief in *magical thought* (i.e., whether it is possible to make something happen by just thinking about it) and belief in *magical action* (i.e., whether it is possible by some action to make an event happen, that is rationally or causally unrelated to that action). For each item, children were required to indicate to what extent they agreed with the statement ('no', 'maybe' or 'yes'). A pre-test with 18 children (10 boys, mean age = 8.7 years) indicated that the MTQ thought subscale (10 items) had a good reliability, Cronbach's $\alpha = .84$, and the MTQ action subscale (10 items) as well, $\alpha = .88$. Accordingly, for the present study all 20 items from the MTQ scale were included.

The locus of control questionnaire (LCQ) was pretested online among 18 children (10 boys, mean age = 8.7 years). We included the 18 items that were used by Nowicki and Strickland (1971). The pre-test indicated that the reliability of the original scale was relatively low (Cronbach's $\alpha = .43$). Based on a factor analysis, 7 items were identified that had high factor loadings on the first factor and these combined items had a moderate reliability (Cronbach's $\alpha = .64$). Accordingly, for the main experiment the 7 items derived from the original locus of control scale for children were included and five additional items were constructed that were closely related to the original items (see Appendix A for the scale that was used in the main study). Still, as reported in the Results section, the reliability of the Locus of Control scale was low. Similar to the MTQ, children were required to indicate their agreement with the statement ('no', 'maybe' or 'yes'). In addition, we asked for participants' gender, age and their belief in God (i.e., 'Do you believe in God?'; 'yes', 'no' or 'maybe'). The questionnaire was administered using a web-based interface on the same experimental computer that was used for the card guessing game. Older children (>8 years) who displayed a good understanding of the questions completed the questionnaire themselves under the supervision of the experimenter. Younger children (<9 years) completed the questionnaire with the help of the experimenter, who read each question aloud and asked the child to verbally report their response.

After having completed the questionnaires, the experimental task was explained to the participant. An overview of the experimental procedure is presented in Fig. 1. Children received the following instruction: *'In this study you will be presented with two playing cards that are rapidly flashing in an alternating fashion. It is your task to select one of two cards by pressing the card that you would like to turn at the right time, in other words: when it is flashed. After you have selected a card, the cards will be turned and you will be shown which card you chose and how much credits you earned. The goal of the game is to collect as many points as possible. We will now start with a short practice.'*

The experiment was conducted on a computer with a touch screen, which enabled a fluent and intuitive experience. At the beginning of the experiment children conducted four practice trials to familiarize with the task. Next, the experiment started, with a total of 24 experimental trials.[2] During the experiment, the score obtained for each trial and the total cumulative score was displayed in the upper right corner of the screen.

[2] We note that we initially tested 5 children with a total number of 40 trials, but in this form the experiment turned out to be too long for the attention span of the children (data from these children was not included in the present analysis).

2.1.4. Data analysis

The questionnaire data were analyzed by calculating the sum score of the items for the different scales, i.e. the Magical Thinking Questionnaire Thought and Action subscales (response alternatives were 'no' = 1, 'maybe' = 2, 'yes' = 3). Items were recoded such that a high value indicated more magical thinking. The Locus of Control Scale items were also scored in terms of three response categories ('no' = 1, 'maybe' = 2, 'yes' = 3); again, items were recoded such that a high value indicated an internal locus of control.

Analysis of the judgmental data (i.e. perceived control and valence) focused on the perceived control across the entire experiment (i.e. averaged across all trials), perceived control as a function of the congruency between the selected and the intended card (i.e., congruent vs. incongruent) and the valence difference between the selected and the unselected card (i.e., higher vs. lower value). The *x*-values of the control-ratings were linearly transformed to a 10-point scale (perceived control: 1 = computer, 10 = self; valence rating: 1 = unhappy, 10 = happy). The judgmental data were analyzed using a repeated measures ANOVA with Congruency (congruent vs. incongruent) and Outcome (higher vs. lower) as within-subjects factors. We included age as a covariate when testing the effects on the judgmental data. The relation between the judgmental data and the questionnaire data was analyzed using a correlation analysis. In different follow-up analyses that are reported in the Supplementary Material Online, we investigated to what extent (1) perceived control differed between the first and the second half of the experiment, (2) to what extent participants developed a specific strategy for selecting a card, (3) to what extent perceived control was affected by the number of congruent vs. incongruent trials over the course of the experiment and (4) to what extent children were aware of the discrepancy between the card that was highlighted at the moment they touched the screen and the card that was ultimately selected.

2.2. Results

2.2.1. Questionnaire results and illusory control and valence judgments

The scores on the subscales of the Magical Thinking Questionnaire and the Locus of Control scale for the different age groups are presented in Table 1 and correlations between the questionnaire data and the behavioral data are presented in Table 2. The reliability of the MTQ Thought subscale was moderate ($\alpha = .63$), the reliability of the MTQ Action subscale was moderate ($\alpha = .72$), and the reliability of the Locus of Control scale was low ($\alpha = .50$). Based on a factor analysis of the Locus of Control scale items, we selected five items that loaded high on the first factor. When these items were combined, the reliability slightly increased to $\alpha = .59$, but for the final analysis we decided to include all original twelve items in the scale.

As can be seen, with increased age the score on the *MTQ Thought subscale* decreased, $r = -.20$, $p < .05$, indicating that older children were less prone to engage in magical thinking. The score on the *MTQ Action subscale* was not significantly correlated with age. The scores on the MTQ Thought subscale were significantly correlated with the scores on the MTQ Action subscale, $r = .39$, $p < .001$. With age, the score on the *Locus of Control scale* increased, $r = .23$, $p < .01$, indicating that older children had a stronger internal locus of control compared to younger children. The scores on the Locus of Control subscale were not significantly correlated with the scores on the MTQ subscales.

The main dependent measure of the card game was *perceived control*, i.e., to what extent the child believed that the turning of the cards was caused by him/herself, as a measure of illusory control. As can be seen in Tables 1 and 2, with increased age, overall perceived control (i.e., across all experimental trials) decreased, $r = -.20$, $p < .05$, indicating that older children experienced less control than younger children over the outcomes in the card game. Age was also correlated with perceived valence, $r = -.39$, $p < .001$, indicating that older children were less happy with the outcomes of the selected cards than younger children. The correlation

Table 2
Pearson's correlations between the questionnaire and behavioral results.

		1	2	3	4	5	6	7
1.	Age	1.0						
2.	MTQ Thought	−.20*	1.0					
3.	MTQ Action	−.07	.39**	1.0				
4.	Locus of Control	.23*	−.05	.08	1.0			
5.	Perceived control	−.20*	.05	.09	−.1	1.0		
6.	# Inc − # Con Trials	.04	−.05	−.05	.03	−.20*	1.0	
7.	Total score	.08	−.11	−.15	.03	.08	−.12	1.0

1 = Age, 2 = Magical Thinking Questionnaire Thought Subscale, 3 = Magical Thinking Questionnaire Action Subscale, 4 = Local of Control Scale, 5 = Perceived control during the card game, 6 = Difference between total number of incongruent and congruent trials, 7 = Total score obtained during the game.
* $p < .05$.
** $p < .001$.

Table 1
Magical thinking, locus of control, perceived control and valence as a function of age.

	Age					
	7 (N = 24)	8 (N = 30)	9 (N = 27)	10 (N = 20)	11 (N = 17)	12/13 (N = 15)
MTQ Thought subscale scores	21.3 (2.9)	22.9 (5.4)	21.4 (2.7)	21.1 (2.7)	20.4 (4.0)	20.1 (3.5)
MTQ Action subscale scores	20.4 (2.3)	22.2 (2.0)	22.0 (2.3)	21.1 (2.3)	21.5 (2.2)	20.2 (1.4)
Locus of Control Scale	25.9 (2.8)	26.2 (3.3)	27.2 (2.2)	27.7 (4.2)	27.7 (3.9)	28.1 (4.0)
Perceived control (card game)	7.1 (1.6)	6.1 (1.7)	6.0 (1.7)	5.7 (1.4)	5.9 (.8)	5.9 (1.8)
Perceived valence (card game)	7.8 (1.5)	7.6 (1.5)	7.2 (1.2)	6.8 (.9)	6.6 (.7)	6.3 (.7)
Interaction-effect Control Rating (card game)	.23 (.41)	1.14 (.55)	.57 (.45)	−.24 (.42)	−.37 (.35)	−.12 (.42)
Interaction-effect Valence Rating (card game)	1.47 (.61)	1.07 (.67)	.87 (.49)	.06 (.65)	.25 (.43)	−.85 (.46)

Scores on the MTQ Thought and MTQ Action subscale could range from 10 (low) to 30 (high), on the Locus of Control scale from 10 (external locus of control) to 30 (internal locus of control) and for the Control Rating from 1 (low control) to 10 (high control). The Interaction-effect for Control Ratings and Valence Ratings was calculated as follows: (Congruent trials: positive–negative outcome) − (Incongruent trials: positive–negative outcome). *SDs* are presented between brackets.

between age and magical thinking, age and locus of control, and age and perceived control persisted when controlling for the other variables when using partial correlations.

The experiment was programmed in such a way that on each trial the outcome of the cards was randomly determined. As a consequence, there was individual variability in the total number of congruent and incongruent trials (i.e., how often the computer selected the card that was intended by the participant), and in the score obtained in the experiment. The average number of trials collected for each category was: congruent win (mean = 6.4, *SD* = 2.1), congruent loss (mean = 5.8, *SD* = 2.1), incongruent win (mean = 6.1, *SD* = 2.3), incongruent loss (mean = 5.7, *SD* = 2.2). As can be seen in Table 2, the difference between the number of incongruent and congruent trials correlated negatively with perceived control, $r = .20$, $p < .05$, indicating that participants who were presented with more incongruent compared to congruent trials experienced lower feelings of overall control as compared to participants who were presented with more congruent compared to incongruent trials. In other words, the overall contingency between the child's actions and the outcomes had a modest impact on participant's awareness of the amount of control they exerted on the outcomes of the game.

2.2.2. Perceived control as a function of congruency and outcome

Fig. 2A presents perceived control during the card game as a function of congruency and outcome, as a measure of sense of agency. Analysis revealed a significant main effect of Congruency, $F(1,132) = 100.0$, $p < .001$, $\eta^2 = .43$, indicating that perceived control was higher when the selected card was congruent with their choice (7.5 ± .17; mean ± *SE*) compared to when the outcome was incongruent with their choice (4.8 ± .21). In addition, a main effect of Outcome, $F(1,132) = 25.2$, $p < .001$, $\eta^2 = .16$, indicates that perceived control was higher when the selected card had a higher value than the unselected card (6.4 ± .14) compared to when the selected card had a lower value than the unselected card (5.8 ± .15). The interaction between the factors Congruency and Outcome was marginally significant, $F(1,132) = 4.4$, $p = .07$, $\eta^2 = .03$, and reflects that the effect of Outcome was slightly stronger for congruent trials compared to incongruent conditions (see Fig. 2A).

Including Age as a covariate in the analysis revealed a main effect of Age, $F(1,129) = 4.4$, $p < .05$, $\eta^2 = .03$, indicating that with increased age overall ratings of control decreased. Importantly, Age did not interact with Congruency, $F(1,129) = 1.2$, $p = .28$, $\eta^2 = .01$, indicating that the effect of outcome congruency on perceived control did not differ as a function of age. A marginally significant interaction between Congruency, Outcome and Age was observed, $F(1,129) = 3.3$, $p = .07$, $\eta^2 = .03$. In order to investigate the directionality of this effect we calculated the difference score between the valence effect for congruent and incongruent trials (i.e.: (Congruent trials: positive–negative outcome) – (Incongruent trials: positive–negative outcome); see Table 1 and Fig. 3A). As can be seen, younger children (especially the 8-year and 9-year olds) were more likely to attribute positive outcomes on congruent trials to themselves, compared to older children. No other effects were found.

2.2.3. Perceived valence as a function of congruency and outcome

Perceived valence ratings are presented in Fig. 2B. A main effect of Congruency, $F(1,132) = 9.8$, $p < .005$, $\eta^2 = .07$, indicates that participants perceived congruent outcomes as more positive (7.4 ± .13) than incongruent outcomes (6.9 ± .15). A main effect of Outcome, $F(1,132) = 145.2$, $p < .001$, $\eta^2 = .52$, reflects that participants perceived selected cards with a higher score than the unselected card as more positive (8.3 ± .12), than selected cards with a lower score than the unselected card (5.9 ± .18). A significant interaction between Congruency and Outcome, $F(1,132) = 6.1$, $p < .05$, $\eta^2 = .04$, indicates that the effect of Outcome was stronger for congruent compared to incongruent trials (see Fig. 2B).

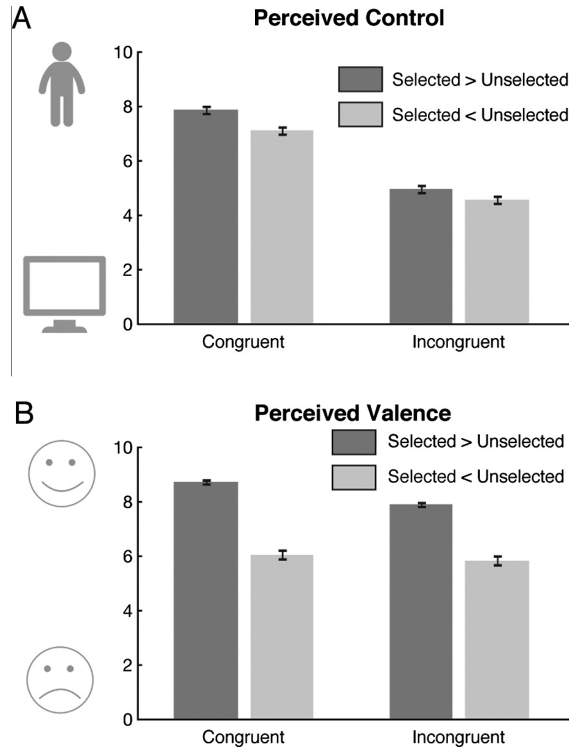

Fig. 2. Perceived control (A) and perceived valence (B) as a function of the congruency of the displayed with respect to the intended card in Study 1. Dark bars represent trials in which the selected card had a higher value than the unselected card. Light bars represent trials in which the selected card had a lower value than the unselected card. Error bars represent standard errors.

Including age as a covariate in the analysis revealed a significant interaction between Congruency, Outcome and Age, $F(1,131) = 6.8$, $p < .01$, $\eta^2 = .05$. Similar to the control ratings, we calculated the difference score between the valence effect for congruent and incongruent trials (i.e.: (Congruent trials: positive–negative outcome) – (Incongruent trials: positive–negative outcome); see Table 1 and Fig. 3A). As can be seen, younger children were more likely to positively value positive outcomes on congruent trials, compared to older children. No other effects were found significant.

2.3. Discussion

The main finding of the first study is that younger compared to older children showed a stronger illusion of control, reflected in the belief that they could control outcomes that were in fact determined by chance. Thus, our findings support the notion that young children are characterized by a strong illusion of control that decreases with age (see also: Weisz et al., 1982). As expected, children reported a stronger feeling of control over outcomes that were congruent with their initial choice, compared to outcomes that were incongruent. However, the effect of outcome congruency did not differ across age groups (see also: Metcalfe et al., 2010 for similar findings in older children). As expected, a self-attribution bias was observed, reflected in higher feelings of control over positive compared to negative outcomes – especially when the outcome was congruent with the intended outcome. The self-attribution bias was somewhat more pronounced for younger compared to older children. The questionnaire data indicate that

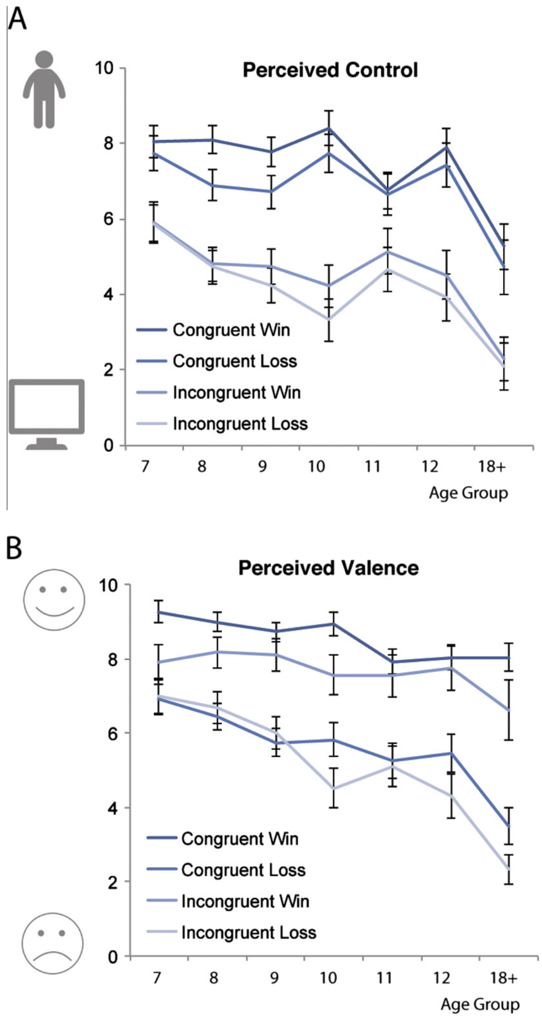

Fig. 3. Perceived control (A) and perceived valence (B) for the different age groups in Study 1 and 2, as a function of the outcome of the trial (congruent-win, congruent-loss, incongruent-win, incongruent-loss). Error bars represent standard errors.

with increased age, magical thinking tended to decrease and the locus of control became more internal. However, no direct relation was observed between the questionnaire data and the findings from the card guessing game.

An interesting question is to what extent the illusion of control, as measured with our newly developed card-guessing game, would further decrease into adulthood. Several studies have shown that adults in general are prone to perceiving illusory contingencies and to overestimating the amount of control that can be exerted over the environment (Blanco, Matute, & Vadillo, 2011; Matute, 1996; Matute, Blanco, & Vadillo, 2008). Based on these findings one may expect that although the overall feeling of control may be lower for adults compared to children, adults would still to a certain extent remain prone to the illusion of control, reflected in a tendency to attribute both congruent and incongruent outcomes to oneself rather than the computer. Thus, in a second study we extended our findings by utilizing a similar experimental paradigm with adult participants.

The resulting comparison between children and adults also allowed us to control for the possible confound that our findings merely reflect that older children show a better understanding of the non-contingent nature of games of chance (Weisz, 1980). With increased practice in the card guessing game, adult participants may become well aware that the outcomes presented are congruent with their intention only on about 50% of all trials. Thus, by increasing the number of trials in Study 2, it could be investigated whether feelings of control decrease over the course of the experiment – which could then be related to an increased awareness of the chance-based nature of the task. In contrast, if feelings of control would not be modulated by experience (similar to the additional analysis pertaining to Study 1 and reported in the Supplementary Material Online), this suggests that the effects observed cannot entirely be attributed to developmental differences in inferential probabilistic reasoning.

3. Study 2: the illusion of control in adults

3.1. Methods

3.1.1. Participants

A total of 16 participants was tested in Study 2 (4 males, mean age = 20.9 years, *SD* = 2.4, age range = 18–25 years). All participants were students at the University of Amsterdam and provided informed written consent before participation. Participants received a financial remuneration for participation in the experiment.

3.1.2. Experimental setup and procedure

A comparable setup and experimental design were used as in the first study. However, instead of using a touch screen participants provided their responses by using a computer keyboard. The left and the right arrow button were used to select the card of their choice and the control and valence ratings were provided through the numerical keyboard. In addition, the number of trials was increased such that in total participants were presented with 80 trials. Similar to the first study, the selection of cards and outcomes was always determined by the computer. The magical thinking and locus of control questionnaires that were used in the previous study were specifically targeted at children and could not be used in the present study. Instead, we included the work locus of control scale (Spector, 1988), the revised paranormal belief scale (Tobacyk, 2004) and the magical ideation scale (Eckblad & Chapman, 1983) to measure superstitious and magical beliefs. These scales were not included in the analysis reported here.

3.1.3. Data analysis

First, in order to allow a direct comparison between the data of both Study 1 and 2, only the first 24 trials were analyzed. The mean control and valence ratings as a function of outcome (congruent vs. incongruent; higher vs. lower) were calculated and analyzed using a repeated measures ANOVA. In a supplementary analysis (see Supplementary Material Online), the data from all 80 experimental trials was analyzed, and in addition the dynamics of control and valence ratings over the course of the experiment were analyzed.

3.2. Results

3.2.1. Perceived control as a function of congruency and outcome

Perceived control ratings for the analysis of the first 24 trials, as a function of valence and outcome are presented in Fig. 3A. A main effect of Congruency, $F(1,15) = 19.4$, $p = .001$, $\eta^2 = .56$ was found, indicating that the feeling of control was higher for congruent (mean = 5.0, *SE* = .6) compared to incongruent outcomes (mean = 2.2, *SE* = .6). No other effects were found (*F*'s < 1.5).

As can be seen in Fig. 3, overall perceptions of control in the current study (with adult participants) were lower than in Study 1 (with children), although the effect of outcome congruency on perceived control (i.e. higher perceived control over congruent compared to incongruent outcomes) and the self-attribution bias (i.e. higher control ratings for positive compared to negative outcomes) were comparable between children and adults. This observation was confirmed by a meta-analysis conducted over both studies, which only revealed a main effect of Age on perceived control, $F(6, 140) = 7.3$, $p < .001$, $\eta^2 = .24$, but did not reveal any interaction effects of Age with the other factors ($Fs < 1$).

3.2.2. Perceived valence as a function of congruency and outcome

Perceived valence for the analysis of the first 24 trials is presented in Fig. 3B. A main effect of Congruency, $F(1, 15) = 6.8$, $p = .020$, $\eta^2 = .31$, indicated that participants were more positive about congruent (mean = 5.8, $SE = .5$) compared to incongruent outcomes (mean = 4.5, $SE = .3$). A main effect of Outcome, $F(1, 15) = 36.1$, $p < .001$, $\eta^2 = .71$, indicated that participants rated 'wins' as more positive (mean = 7.3, $SE = .4$) compared to 'losses' (mean = 2.9, $SE = .6$). No significant interaction was found between outcome and congruency ($F < 1$).

As can be seen in Fig. 3, the overall valence ratings in Study 2 (with adult participants) were lower than in Study 1 (with children), and the difference in perceived valence between 'wins' and 'losses' tended to increase with increased age. Indeed, a meta-analysis across both studies, showed a main effect of Age on perceived valence, $F(6, 140) = 10.3$, $p < .001$, $\eta^2 = .31$ and an interaction between Age and Outcome was observed, $F(6, 140) = 2.7$, $p = .015$, $\eta^2 = .11$.

3.3. Discussion

Study 2 extended the findings obtained in Study 1 by showing that overall perceptions of control in a game of chance further decreased from childhood into adulthood. Still, adults showed a comparable effect of outcome congruency on perceived control as in children, indicating that sense of agency is similarly affected by the match between predicted and observed outcomes in both children and adults (see also: Metcalfe et al., 2010). Interestingly, our findings also show that with increased age the illusion of control decreases, but does not completely vanish, as reflected in control ratings well above zero for both congruent and incongruent action outcomes.

In the second study an increased number of trials was used compared to the first study, thereby further enabling participants to infer the non-contingent nature of the task that was used. However, reported feelings of control did not significantly decrease over the course of the experiment (see Supplementary Material Online; Section 2.1), indicating that the effects observed did not entirely depend on experience or on probabilistic learning about the non-contingent nature of the task (Weisz, 1980). This finding also argues against the notion that the illusion of control in our studies simply developed due to a process of reinforcement or associative learning (Blanco et al., 2011; Matute, 1996). Rather, illusory control is likely related to participant's prior beliefs that they can control certain outcomes – even though the explicit strategy whereby such an outcome could be obtained was left implicit (i.e. participants were only instructed that they should press a card at the correct time, but no information was given regarding which card should result in higher outcomes).

4. General discussion

4.1. Overview of the main findings

The present study assessed the development of the illusion of control, sense of agency, and the self-attribution bias. Overall, our findings support the notion that young children are characterized by a strong illusion of control that decreases with age (see also: Weisz et al., 1982). This illusion of control was more pronounced for younger compared to older children and more pronounced for children compared to adults. The decrease in the illusion of control with age is corroborated by our questionnaire data, indicating that magical thinking decreased with age, thereby replicating and extending earlier studies that focused on younger children (i.e. 4 and 5 year olds; cf. Bolton et al., 2002; Evans, Milanak, Medeiros, & Ross, 2002; Rosengren & Hickling, 1994; Rosengren et al., 1994; Subbotsky, 2004).

We did not find a difference between younger and older children, nor between children and adults, for the main effects of outcome congruency and valence on perceived control. That is, we found that participants reported higher feelings of control over congruent compared to incongruent outcomes irrespective of their age. This observation replicates and extends classical findings in research on sense of agency in adults, in which similar effects of outcome congruency on perceived agency have been reported (Farrer et al., 2003; Fourneret & Jeannerod, 1998; van den Bos & Jeannerod, 2002). Below we will discuss the behavioral and self-report effects that were observed in relation to previous literature on this topic.

4.2. The development of illusory control

Our findings – based on a card guessing game – indicate that perceived control over the outcomes of such a task decreases with age. Previous studies have shown that presenting a chance game as a skill-oriented task enhances illusions of control (Presson & Benassi, 1996; Stefan & David, 2013). The illusion of control that was observed in the present study may be related to the instruction that placed emphasis on the strategy or skills that could be used to obtain the card of their choice. However, in contrast to previous findings indicating that the pattern of wins/losses may induce a skill-oriented approach and result in the illusion of control (Frank & Smith, 1989; Langer, 1975), we did find no evidence for 'successful performance' early on in the experiment on feelings of illusory control (see Supplementary Material Online; Section 1.3). This may be related to the fact that in our experiment, outcomes were randomly generated and the pattern of wins/losses was not explicitly manipulated. Still, the suggestion that children performed the card guessing game with a skill-based orientation was supported by the finding that they used a color-based strategy, by selecting cards with a color that was indicative of wins on the preceding trial (see Supplementary Material Online; Section 1.2). This strategy-related approach did not differ between age groups, indicating that children of all age groups tended to approach the card-guessing game with a skill-oriented strategy, thereby extending classical findings on games of chance in adults to children (Langer, 1975; Langer & Roth, 1975).

It could be argued that the effects observed in the card guessing game were merely a logical consequence of the fact that participants were instructed to strategically select a card (i.e. by pressing a card at the correct time). Younger children may have been more prone to accepting and believing this 'skill-oriented' suggestion, whereas older children and adults soon came to realize that they were in fact dealing with a game of chance. On this account, it should be expected that for older children and adults the feeling of control decreases over the course of the experiment. However, we did not find evidence for such an overall decline in the feeling of control over the course of the experiment (Supplementary Material Online; Sections 1.1 and 2.1). Thus, we believe that the decline in the illusion of control with increased age cannot be entirely accounted for by young compared to older children being more prone to accepting the suggestion that the outcomes of the task could be controlled.

The older children in our study may have had a better understanding of chance events than younger children, which enabled them to infer that they were dealing with a chance event rather than a task that required specific skills. Although such an explanation would be in line with a Piagetian view on the development of concepts of chance and probability-which were previously thought to emerge only around 12 years of age (see e.g., Hoemann & Ross, 1982) – more recent studies indicate that young infants already master a basic notion of probability (Denison, Reed, & Xu, 2013; Denison & Xu, 2014; Gonzalez & Girotto, 2011; Schlottmann, 2001). We note that the sharpest drop in illusory feelings of control was observed when comparing the seven to eight year old children, whereas both age groups should have a similar understanding of chance events according to the literature mentioned above (e.g. the children participating in our study were all above the age of the youngest group of participants that were tested in previous studies on illusory control in children; cf. Weisz, 1980, 1981; Weisz et al., 1982). Furthermore, our supplementary analyses indicate that younger compared to older children did not differ in their perceived control over the course of the experiment, or as a function of the pattern of wins/losses and or congruent/incongruent trials experienced during the task (reported in the Supplementary Material Online).

Rather than being related to a differential understanding of chance events, the overestimation of control may offer young children the opportunity to optimally exploit their environment, by using every chance to exert control over external events (Haselton & Nettle, 2006). Especially for children, who are continuously faced with changes in their environment and their bodily and cognitive capabilities, a bias toward overestimating the amount of control may be beneficial (Heckhausen & Schulz, 1995). In contrast, in adults the overestimation of control may become more situation specific: especially when confronted with threatening, uncertain or ambiguous situations, people may be more likely to develop illusions of control (Keinan, 1994, 2002; Malinowski, 1955; Rudski & Edwards, 2007).

4.3. The development of sense of agency

In our first study we found that perceived control was higher for outcomes that were congruent with the child's intention compared to incongruent outcomes. This finding is in line with previous studies with adults, showing that the congruence between intended and observed action outcomes is a strong predictor of sense of agency (Aarts et al., 2009; Daprati et al., 1997; Farrer et al., 2003; Jeannerod, 1994; van der Weiden et al., 2013). Our findings suggest that a similar process can be observed in children, who likely relied on the spatial compatibility between the intended and the selected card, to infer their sense of agency. Interestingly, the effect of congruency on perceived control did not differ between different age groups, suggesting that detecting action-outcome congruencies is a very basic process that is already well established at a young age and persists across the lifespan (David et al., 2008). Thereby, our finding extends previous work in 8–10-year old children indicating that agency ratings in both children and adults were similarly affected by the congruency between performed and observed movements (Metcalfe et al., 2010). Furthermore, whereas younger children may tend to confuse incidental and accidental outcomes (cf. Metcalfe et al., 2010; Shultz & Wells, 1985; Shultz et al., 1980) and may change their retrospective awareness of prior intentions based on the outcome of an action (cf. cf. Astington, 2001; Phillips et al., 1998; Shultz & Wells, 1985), apparently 7-year old children are already well capable to infer agency based on the congruency between intended and observed outcomes.

In addition, we found that children showed a self-attribution bias; i.e., they indicated higher feelings of control for positive outcomes (i.e., the selected card had a higher value than the unselected card) compared to negative outcomes (i.e., the selected card had a lower value than the unselected card). This effect tended to be more pronounced for trials in which the outcome was congruent as opposed to incongruent with the intended action (i.e. reflected in the interaction between Congruency and Outcome), suggesting that congruency and valence information was processed in a hierarchical fashion (i.e. children likely first attended to the location of the selected card and subsequently processed the valence of both cards). The effect of enhanced feelings of control over positive congruent outcomes compared to negative congruent outcomes was most pronounced for younger compared to older children. This finding replicates earlier studies showing a decrease in the self-attribution bias with increased age (for review, see: Mezulis et al., 2004) and the present findings qualify this observation by showing that the self-attribution bias in young children is most pronounced for congruent compared to incongruent outcomes.

4.4. Magical thinking and control measures

In the present studies illusory control, magical thinking and locus of control varied systematically as a function of age. However, no direct relation was observed between the judgmental data from the card guessing game and the self-report scales. It could well be that the different measures actually reflect different theoretical constructs of control (Skinner, 1996; Skinner, Chapman, & Baltes, 1988). This is supported by the partial correlations analyses, indicating that the relations between age and the different experimental measures (i.e., magical thinking, perceived control and locus of control) were statistically independent. In their influential two-process model of perceived control, Rothbaum et al. distinguish 'primary control' from four different types of 'secondary control', of which only one reflects the illusion of control (i.e., attributing chance outcomes to ability). The magical thinking questionnaire that was used in the present study primarily assesses children's beliefs about the contingency between two events in the external world (if 'A' happens, does 'B' occur?), and as such this measure primarily represents *'means-ends beliefs'* or *'predictive control'* (Rothbaum et al., 1982). In contrast, the perceptions of control question in the card guessing game was directly related to the child's perceived control as a human agent in a specific experimental setting, which has been labeled *'control beliefs'* (Skinner, 1996) or *'illusory control'* (Rothbaum et al., 1982). Finally, the locus of control questionnaire assessed to what extent the child believed that as an agent (s)he possessed specific means to bring about an effect in the external world (i.e. '*agent beliefs' or 'primary vs. vicarious control'*). Although these constructs are of course theoretically related, in the present study they pertained to different domains (e.g., school, parents, social relations, the card guessing game) and as such they may not reflect generalized feelings of control.

5. Conclusions

We found that illusory control and the self-attribution bias in a card guessing task decrease as children grow older. In contrast, for both children and adults sense of agency in the task was similarly affected by outcome congruency, suggesting that the ability to relate predicted action outcomes to observed action outcomes reflects a basic mechanism that helps people to sustain a sense of agency.

Acknowledgments

This research was part of Science Live, the innovative research program of Science Center NEMO that enables scientists to carry out real, peer-reviewed research using NEMO visitors as volunteers. This research was supported by a VENI grant no. 016.135.135 to the first author from the Netherlands Organization for Scientific Research (NWO). We would like to thank the research assistants (Charis, Elsa, Eva Laura, Monique, Olmo and Rascha) for their help with data collection.

Appendix A

Adjusted children locus of control scale

Dutch:
1. Als ik echt mijn best doe win ik vaak bij spelletjes
2. Denk je dat goede dingen gebeuren omdat je er hard voor gewerkt hebt?
3. Hoe ik ook mijn best doe, het lijkt weinig uit te maken.
4. Denk je dat als iemand goed zijn best doet met leren, het ook altijd goed gaat op school?
5. Denk je dat je ouders meestal luisteren naar wat jij te zeggen hebt?
6. Op school hebben leerlingen eigenlijk niets te vertellen.
7. Vind je vaak dat het moeilijk is om je ouders op andere gedachten te brengen?
8. Heb je vaak het gevoel dat als je erg je best doet op school je ook hogere cijfers haalt?
9. Meestal heeft het geen zin om hard je best te doen; de meeste dingen lopen toch niet goed af.
10. Denk je dat kinderen altijd hun zin krijgen als ze maar blijven proberen?
11. Als je echt iets heel graag wilt lukt dat dan meestal ook?
12. Vaak heb je weinig te vertellen en moet je maar gewoon doen wat je gezegd wordt.

English:
1. As long as I really put in effort, I often win at games
2. Do you feel that when good things happen, they happen because of hard work? (N&S 1973 item# 32)
3. No matter how hard I try, my efforts do not seem to have much effect.
4. Do you believe that if somebody studies hard enough, he or she can pass any subject? (N&S 1973 item# 6)
5. Do you feel that most of the time parents listen to what their children have to say? (N&S 1973 item# 9)
6. Pupils in school really have no say in things at all.
7. Do you feel that it is nearly impossible to change your parent's mind about anything? (N&S 1973 item# 14)
8. Do you often feel that whether you do your homework has much to do with what kind of grades you get? (N&S 1973 item# 22)
9. Do you feel that most of the time it doesn't pay to try hard because things never turn out right anyway? (N&S 1973 item# 7)
10. Do you think that kids can get their own way if they just keep trying? (N&S 1973 item# 30)
11. If you really want something, are you usually able to get it?
12. Often you don't really have a say and really the only option is just to do what you're told

Appendix B. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2015.08.004.

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