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Attentional focus versus diffuse attention: Which is better in toddlers?

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Abstract

How toddlers' attention is distributed in the visual field during a magic trick was examined using three expectation conditions. Results showed that 2.5-year-old children assigned to the condition with major task-relevant information (i.e., a verbal cue to attend to one of the visual targets) (i) outperformed those who were assigned to the condition with no task-relevant information, (ii) displayed more attentional switches between visual targets than those who were assigned to the condition with no task-relevant information, and (iii) did not look significantly longer at one of the visual targets in contrast to children assigned to the condition with no task-relevant information. The findings of an additional control condition suggest that the performance by children in the condition with major task-relevant information cannot merely be the consequence of the larger quantity of auditory information that was given during the interaction prior to the magic trick. In our task, verbal cue affected the switching of attention, not the prioritization of a specific region of space. These results are discussed in terms of advantage conferred by a diffuse mode of attention.

Keywords

attention switching, spatial attention, visual attention

How visual attention drives the search behaviour is still poorly described in toddlers. Visuospatial attention can be distributed over a broad region, focused on a small region, or deployed to multiple locations simultaneously (Jefferies, Enns, & Di Lollo, 2014). Selective attention allows us to prioritize some aspects of information while ignoring others by focusing on a certain part of the environment. Posner, Snyder and Davidson (1980) used the metaphor of the spotlight to characterize the space-based mechanism of selective attention. This is the idea that selective attention shifts from one location to another in the visual space so that the stimuli within these selected regions are processed preferentially. Space-based attention is adaptive in situations that require attention to tiny details. Thus, a causal link has been established between attentional focus and toddlers' performance on some visuospatial tasks (Blaser, Eglington, Carter, & Kaldy, 2014; Kaldy, Giserman, Carter, & Blaser, 2016). More precisely, the use of focused attention increases the accuracy for finding hidden targets in visual search tasks. In contrast, this attentional mechanism is detrimental in situations that require broad perception of the environment, that is diffuse attention. For instance, Rivière and Brisson (2014) have recently shown in 2.5-year-olds that space-based attention can lead to difficulty disengaging covert attention from a specific place even if there is a salient change in the environment. In this study, the authors investigated how toddlers' attention is distributed in the visual field during a manual search task for objects moving out of sight, namely the moving boxes task. Findings suggest that the primacy of space-based attention over object-based attention may cause the failure of some toddlers in this task. Indeed, results showed that the 2.5-year-olds who failed the moving boxes task allocated more attention to the location of the relevant object than to the object itself.

Although selective attention difficulties in toddlerhood are well documented (e.g. Berthier, Deblois, Poirier, Novak, & Clifton, 2000; Butler, Berthier, & Clifton, 2002; Jenkins & Berthier, 2014) considerably less is known about the mechanisms underpinning these difficulties. In a recent study, Rivière and Falaise (2011) have shown how top-down processes underlie an attentional focus phenomenon observed in 2.5-year-olds who are presented with a three-location search task involving invisible displacements of an object, namely the C-not-B task. The authors argued that, in this task, (i) the motion of the experimenter's hand grabbed the attention of the toddlers; and (ii) this attentional focus phenomenon precluded attentional switching in toddlers. Further research is needed to understand more about the complex interplay between the costs and benefits associated with a specific attentional mechanism, such as attentional focus or diffuse attention. The present study was designed to shed light on these attentional mechanisms in toddlers.

General rationale

In the present study, we investigated how toddlers' attention is distributed in the visual field during a magic trick involving a sequence of action with a puppet, namely the speaking puppet task. This magic trick derived from the task designed by Kuhn and Findlay (2005) and Kuhn and Tatler (2010). In Kuhn's situation, the effect was the disappearing of a lighter and a cigarette; the method was for the magician to simply drop the items into his lap. As we performed this trick for toddlers, a puppet and its pacifier were used instead of a cigarette and a lighter. The present study considered how expectations affect attentional dynamics in toddlers

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who are presented with a magic trick. In toddlers, there is evidence that top-down processes underlie the attentional focus phenomenon observed in some spatial search tasks (e.g. Rivière & Falaise, 2011). Therefore, we predicted the prioritization of a specific region of space (i.e., the pacifier) in children who receive major task-relevant information (i.e., a verbal cue to attend to the pacifier). Based on previous research, we also expected more attentional switches between three visual targets in children who receive major task-relevant information as compared with children who receive no task-relevant information.

Method

Participants

A total of 72 children (35 girls and 37 boys) with a mean age of 2 years 6 months 15 days (*SD* = 1 month 16 days) were tested. These children were from a middle-class socioeconomic background. They were from an urban setting and were recruited from preschools in France.

Procedure

All children watched an adult demonstrating a magic trick involving a sequence of actions with a puppet (47 cm × 19 cm), namely the speaking puppet task. The child was seated facing a small table. The experimenter was seated on the opposite side of the table. He held a puppet in his hand. The experimenter took the puppet's pacifier off. He moved it away from the puppet and kept it in elevated position. The experimenter's gaze followed pacifier's displacement. Then he looked at the child and mimicked the puppet's voice. During this speech, the experimenter dropped the pacifier on the floor. Finally, the child was asked to find the pacifier. The child heard the speech as follows:

> Look! I brought my puppet. It is nice. But, I got the feeling that it wants to tell you something. I am going to take its pacifier off, that way it will be able to speak to you. I'll put the pacifier here, OK?

Then the experimenter mimicked the puppet's voice:

> Hello, my name is Lisa. I am a little puppet. I like to play with children. We have fun all day long. I would like to get my pacifier back because I am tired and I would like to go to bed.

Finally, the experimenter went back to his natural voice and said:

> Where is the pacifier? Can you show it to me with your finger?

Two consecutive test trials were administered. The position of the puppet was consistently either to the left or to the right of the child throughout the session. The puppet's position (to the left or to the right of the child) was balanced between participants. Each trial ended when the child searched for the hidden pacifier or after 1 min if no search occurred. Participants were classified as successful if they showed a search behaviour towards the floor where the pacifier was. Children who did not search successfully were shown the correct location of the object, and an incorrect response was scored. The child's looking behaviour was recorded using a camera which was positioned in front of her face. Given that the task was performed live to each participant, it was important to ensure that there was a reasonable degree of consistency in the way the task was performed. The task's length during a trial was similar between participants (mean = 20.98 sec, *SD* = 2.19 sec). Thus, any looking time differences in children cannot be artefacts of the way in which the task was performed.

There were three experimental conditions: (a) the speaking puppet condition with no task-relevant information; (b) the condition with minor task-relevant information, in which the experimenter said to the child "Be careful because something is going to happen", and (c) the condition with major task-relevant information, in which the experimenter said to the child "Be careful of the pacifier". In conditions with minor and major task-relevant information, the information was given prior to the start of the magic trick and in the presence of the puppet and pacifier. In both conditions, the adult looked at the child when giving the information. In all conditions, the experimenter dropped the pacifier on the floor when saying the word "we".

Children were randomly assigned to one of the three groups, with the result that 24 children were tested in the first condition (12 girls and 12 boys, mean age = 2 years 6 months 22 days, *SD* = 28 days), 24 were tested in the second condition (12 girls and 12 boys, mean age = 2 years 6 months 8 days, *SD* = 41 days), and 24 were tested in the third condition (11 girls and 13 boys, mean age = 2 years 6 months 14 days, *SD* = 38 days).

In the condition with major task-relevant information (i.e., a verbal cue to attend to the pacifier), children were presented with a situation that was analogous to that used in the condition with no task-relevant information except for the fact that children were instructed to be careful of the pacifier. In the condition with minor task-relevant information (i.e., a global verbal attention cue), children were presented with a situation that was analogous to that used in the condition with no task-relevant information except for the fact that children were instructed to be careful because something was going to happen. This condition was an additional control condition to check whether the possible effect was due to the information and not the interaction prior to the magic trick.

Data analysis

For each participant, success or failure was scored as well as looking time on each of the three visual targets (experimenter's face, puppet, and pacifier). Looking times were coded from video using the software AVIDEMUX. One observer scored all trials. The observer coded how much time each child spent looking at each of the three visual targets.

The child's gaze was coded manually from video of the child's face. A distance of 40 cm separated the experimenter's face and both the puppet and the pacifier (see Figure 1). The puppet and the pacifier were separated by a distance of 120 cm. These distances let the coder determine the target of the child's attention. The observer also coded the number of attentional switches between visual targets. Participants were given a 1 if their gaze shifted away from a visual target to a new visual target. As a check on the reliability of scoring, the looking distributions, the number of attentional switches, and success/failure response of the quarter of the participants were coded by a second observer. The agreement of both observers on success/failure response, looking times, and the number of attentional switches is large (respectively, Kappa = 1, $p < .001$; $r = 0.57$, $p < .05$; $r = 0.62$, $p < .05$; Cohen, 1988).

Figure 1. Photo of the magic trick with the three visual targets (puppet, experimenter's face, and pacifier).

Results

The crucial trial of this experiment is the first one, because toddlers' performance on the subsequent trial may be affected by their first trial experience. Therefore, chi-square tests were performed on the scores from the first test trial. As shown in Figure 2, the performance of participants in the condition with major task-relevant information was significantly superior to that of participants in the condition with no task-relevant information, $X^2_{(1)} = 4.09$, $p = .04$, $\eta^2_p = .29$. Although the dropping pacifier was fully visible, only 9 (37%) participants in the condition with no task-relevant information demonstrated a search behaviour in the direction of the floor where the pacifier was. The performance of participants in the condition with minor task-relevant information did not differ from either that of controls in the condition with no task-relevant information, $X^2_{(1)} = 2.09$, $p = .14$, $\eta^2_p = .20$, or that observed in participants in the condition with major task-relevant information, $X^2_{(1)} = 0.36$, $p = .55$, $\eta^2_p = .08$.

A McNemar's test of related samples indicated that the difference between performance on the first trial and the second trial was not significant in the condition with no task-relevant information, X^2 (1, $N = 48$) = 0.41, $p = .52$, in the condition with minor task-relevant information, X^2 (1, $N = 48$) = 0.28, $p = .59$, and in the condition with major task-relevant information, X^2 (1, $N = 48$) = 0.03, $p = .85$.

To detect attentional dynamics underpinning children's performance in this task, looking times were calculated for each of the three visual targets (see Table 1). A 3 (Location: experimenter's face, puppet, or pacifier) × 3 (Condition: "no task-relevant information", "minor task-relevant information", and "major task-relevant information") × 2 (Trial: first or second) repeated measures ANOVA was performed on children's looking times. This analysis yielded a significant interaction between visual target and condition, $F(3.7, 256) = 3.39$, $p = .01$, $\eta^2_p = .05$. This interaction was broken down into simple main effects. There were no significant differences between conditions concerning looking times on experimenter's face and puppet, respectively, $F(2, 141) = 0.75$, $p = .47$, $\eta^2_p = .01$; $F(2, 141) = 1.59$, $p = .20$, $\eta^2_p = .02$. The difference between conditions concerning looking times on pacifier was significant, $F(2, 141) = 7.91$, $p < .001$, $\eta^2_p = .10$. Bonferroni post hoc comparisons showed that participants in the condition with no task-relevant information looked a significantly shorter time at the pacifier (m = 3.18 s, $SD = 2.52$ s) than both participants in the condition with major task-relevant information (m = 5.97 s, $SD = 4.66$ s, $p < .001$) and participants in the condition with minor task-relevant information (m = 4.93 s, $SD = 2.85$ s, $p = .04$). There is no statistical difference concerning looking times on pacifier between participants in the condition with minor task-relevant information and participants in the condition with major task-relevant information ($p = .43$).

The patterns of looking time have also been tested for each condition. In the condition with no task-relevant information, the difference between visual targets was significant, $F(2, 94) = 20.65$, $p < .001$, $\eta^2_p = .30$. Bonferroni post hoc comparisons showed that participants looked significantly longer at the experimenter's face (m = 7.66 s, $SD = 3.47$ s) than both pacifier (m = 3.18 s, $SD = 2.52$ s, $p < .001$) and puppet (m = 4.96 s, $SD = 2.85$ s, $p = .001$). Participants looked significantly longer at the puppet than pacifier ($p = .007$). In the condition with minor task-relevant information, the difference between visual targets was significant, $F(2, 94) = 10.21$, $p < .001$, $\eta^2_p = .17$. Bonferroni post hoc comparisons showed that participants looked significantly longer at the experimenter's face (m = 7.47 s, $SD = 3.9$ s) than both pacifier (m = 4.93 s, $SD = 2.85$ s, $p = .002$) and puppet (m = 4.16 s, $SD = 3.23$ s, $p < .001$). There is no statistical difference concerning looking times between puppet and pacifier ($p = 28$). In the condition with major task-relevant information, there is no statistical difference between visual targets, $F(2, 94) = 1.57$, $p = .21$, $\eta^2_p = .03$.

The interaction between overall looking time and condition was significant, $F(2, 261) = 3.86$, $p = .02$, $\eta^2_p = .05$. Bonferroni post hoc comparisons showed that participants in the condition with major task-relevant information looked significantly longer at the three visual targets (m = 17.94 s, $SD = 4.23$ s) than participants in the condition with no task-relevant information (m = 15.8 s, $SD = 2.94$ s, $p = .02$). There is no statistical difference concerning overall looking time between participants in the condition with minor task-relevant information (m = 16.57 s, $SD = 4.12$ s) and participants in the condition with no task-relevant information ($p = .97$) as well as participants in the condition with major task-relevant information ($p = .24$).

The main effect of trial was significant, $F(1, 138) = 18.59$, $p < .001$, $\eta^2_p = .11$. The children looked longer at the visual targets in the first trial than in the second trial. Both the trial × location interaction and the trial × condition interaction were not significant (respectively, $F(1.9, 256) = 2.08$, $p = .13$, $\eta^2_p = .01$; $F(1, 138) = 0.003$, $p = .99$, $\eta^2_p = .00$).

Finally, the difference between conditions concerning the number of attentional switches between visual targets was significant, $F(2, 141) = 6.04$, $p = .003$, $\eta^2_p = .07$. Bonferroni post hoc comparisons showed that participants in the condition with major task-relevant information switched their attention between visual targets significantly more often (m = 14.97 s, $SD = 5.69$ s) than both participants in the condition with no task-relevant information (m = 11.85 s, $SD = 4.10$ s, $p = .004$) and participants in the condition with minor task-relevant information (m = 12.54 s, $SD = 3.70$ s, $p = .03$). There is no statistical difference concerning the number of attentional switches between visual targets between participants in the condition with minor task-relevant information and participants in the condition with no task-relevant information ($p = 1$).

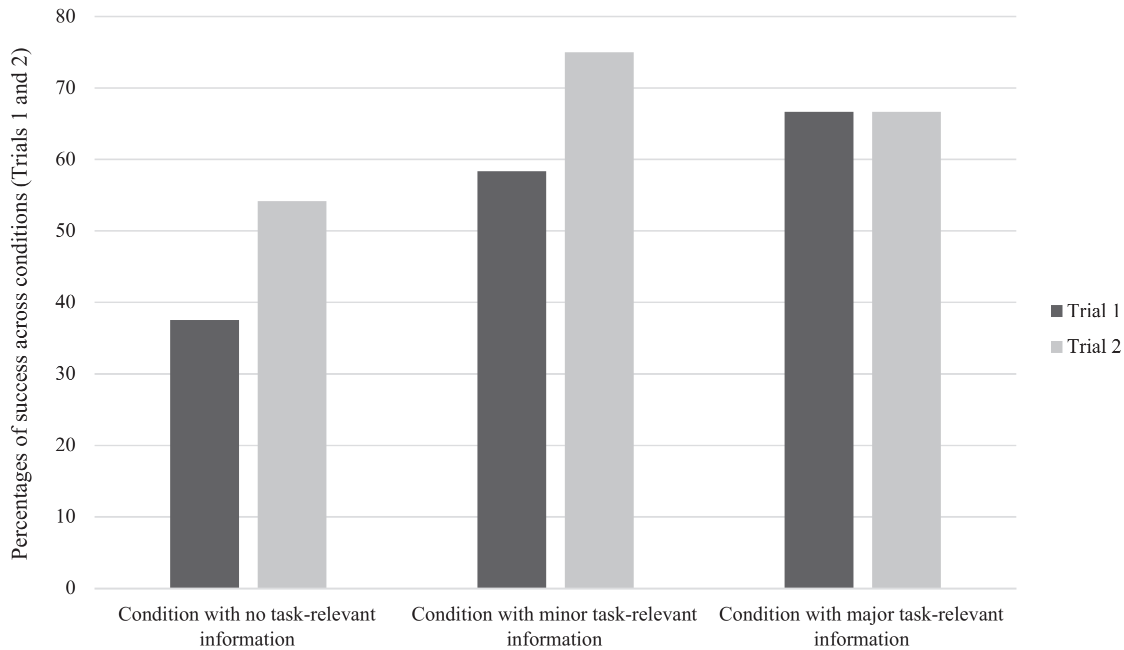

Figure 2. Percentages of success across conditions (Trials 1 and 2).

Table 1. Mean looking times in seconds (with standard error of the mean) of children on each of the three visual targets across conditions (Trials 1 and 2).

Visual target	Experimenter's face	Puppet	Pacifier
Condition with no task-relevant information	7.66 (3.47)	4.96 (2.85)	3.18 (2.52)
Condition with minor task-relevant information	7.47 (3.9)	4.16 (3.23)	4.93 (2.85)
Condition with major task-relevant information	6.77 (3.85)	5.19 (2.78)	5.97 (4.66)

Note. The number of children in each condition is 24.

General discussion

The present experiment was carried out to investigate how expectations influence both toddlers' performance and attentional deployment in a magic trick situation. The results indicate that 2.5-year-old children assigned to the condition with major task-relevant information (i.e., a verbal cue to attend to one of the visual targets) (i) outperformed those who were assigned to the condition with no task-relevant information, (ii) displayed more attentional switches between visual targets than those who were assigned to the condition with no task-relevant information, and (iii) did not look significantly longer at one of the visual targets in contrast to children assigned to the condition with no task-relevant information. The performance in both conditions was not significantly different to performance of participants in the condition with minor task-relevant information (i.e., a global verbal attention cue). These results suggest that the performance by children in the condition with major task-relevant information is not likely due to the amount of auditory information that was given during the interaction prior to the magic trick.

These findings and their interpretations are discussed in several contexts. First, we discuss whether the significant differences in terms of the spread of attention by children assigned to both the condition with no task-relevant information and the condition with minor task-relevant information could be interpreted as a research of additional social information. Second, we discuss our results in terms of advantage conferred by a diffuse mode of attention with respect to previous studies investigating attentional dynamics in toddlers who are presented with visual search tasks.

In the present study, results show that children assigned to both the condition with no task-relevant information and the condition with minor task-relevant information look significantly longer at the experimenter's face than two other visual targets. Where does this attentional focus on the experimenter's face phenomenon come from? A possible explanation may lie with the particular status of the face. Some authors suggested that a system combines nonverbal behavioural cues displayed by people around us (gaze direction, head orientation, gestures, and postures) to process the direction of social attention. Thus, Perret and Emery (1994) suggested that the superior temporal region of the macaque brain that responds to conjunctions of eye, head, and body position detects the direction of another individual's social attention. Because of the value of such a cue in daily life, this source of information carries an important weight in the decision process. Moreover, Vivanti, Nadig, Ozonoff, and Rogers (2008) have shown that typically-developing children look at the demonstrator's face more when observing non-meaningful gestures than when observing meaningful actions on objects. In our study, the attentional focus to the experimenter's face that we observed in children assigned to both the condition with no task-relevant information and the condition with minor task-relevant information could be interpreted as a search for additional social information (e.g. the direction of the adult's gaze) in order to understand the experimenter's action.

Although the development of selective attention and the deployment of attention switching have been studied in separate literatures (for a review, see Hanania & Smith, 2010), these appear to be highly related phenomena. Indeed, recent studies have shown the tight connection between attentional focus phenomenon and attentional switching difficulties in toddlers. Thus, Rivière and Falaise (2011) argued that an attentional focus phenomenon on the motion of the experimenter's hand precludes attentional switching in 2.5-year-olds who are presented with a three-location search task involving invisible displacements of an object, namely the C-not-B task. Recently, Rivière and Brisson (2014) investigated how 2.5-year-olds' attention is distributed in the visual field during a manual search task for objects moving out of sight, namely the moving boxes task. Findings suggest that in toddlers, space-based attention (attentional spotlight) can lead to difficulty disengaging covert attention from a specific place even if there is a salient change in the environment. In our study, the attentional focus to the experimenter's face that we observed in children assigned to both the condition with no task-relevant information and the condition with minor task-relevant information could generate attentional switching difficulties.

In the present study, children who were given major task-relevant information correctly searched for the pacifier on the floor more often than children who were given no task-relevant information. The performance in both conditions was not significantly different to performance by children who were given minor task-relevant information. The improvement of performance observed in 2.5-year-old children assigned to the condition with major task-relevant information did not entail the prioritization of a specific region of space. Moreover, participants in the condition with major task-relevant information looked significantly longer at the three visual targets and switched their attention more than participants in the condition with no task-relevant information. These findings suggest that children's top-down control over visual attention plays a crucial role in our situation. More precisely, the activation of top-down processes by the verbal cues may facilitate the diffusion of ample attentional resources over a broad spatial region of the visual field. The other aspect of the data that argues for top-down processes influencing visual attention is that participants in the condition with major task-relevant information switched their attention more than participants in the condition with minor task-relevant information. Indeed, this result suggests that specific information gives a stronger effect than general information compared to the control condition.

It could be hypothesized that the verbal cue to attend to one of the visual targets used in the present study is less salient than the visual cue used in previous studies, at least when considering visual selective attention.[1] It should be noted, however, that the influence of verbal cues (i.e., concise phrases, often just one or two words) on selective attention to visual inputs has been acknowledged for quite some time (cf. Landin, 1994). In children, research has shown that verbal cues provided during preliminary instructions draw the participants' attention to critical task stimuli (e.g. Kray, Schmitt, Heinz, & Blaye, 2015; Perreault & French, 2016). In the present study, participants in the condition with no task-relevant information looked significantly shorter at the pacifier than both participants in the condition with major task-relevant information and participants in the condition with minor task-relevant information. This result highlights the role of top-down processes on toddlers' attention.

In our analysis, children assigned to the condition with major task-relevant information succeeded on our magic trick by allocating their attention in an unfocused way, like a lantern. Indeed, the ability to view the scene holistically seems to play a key role in toddlers' success in the present task. While research demonstrates that the use of focused attention increases toddlers' accuracy for finding hidden targets in visual search tasks (e.g. Blaser et al., 2014; Kaldy et al., 2016), our results suggest that in toddlers a successful search for hidden objects can be conducted with attention devoted to a large portion of the visual field. We argue that the capacity to view the scene holistically may constitute an optimal strategy in some contexts. Thus in our task, this optimal allocation of attentional resources allows the child to exhibit a high probability of pacifier detection. Dealing with a complex environment requires focusing on relevant stimuli and ignoring distractors. However, a too strong or too sticky attention that makes for difficult switching has been considered as a property of not quite complete and immature selective attention (cf. Hanania & Smith, 2010; Rivière & Brisson, 2014). By showing that toddlers' successful performances in some spatial tasks occur outside an exclusively focal mode of attention, our results demonstrate the need for investigations of diffuse attention in young children.

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