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Does the experimenter presence impact children's working memory?

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ABSTRACT

The literature on audience effect shows that the presence of even a single person is enough to undermine performance in tasks relying on executive functions. This detrimental effect would result from the automatic capture of attention. Despite evidence in adults, investigations are still lacking in children. Here, we tested for the first time whether the common situation in psychology research to have an experimenter present at testing may impact children's working memory (WM). According to the attentional capture hypothesis, and in line with adults' findings, an experimenter presence effect should be observed when children use attention for WM maintenance, that is after the age of 7, and younger children should be immune to this effect. The experimenter presence was manipulated in a complex span task in which children memorised names of pictures or letters while naming colours of smileys aloud. Across three experiments, we varied the age of our participants (5, 8 and 11), the memory test (recognition and serial recall), and the difficulty of the secondary task by changing the speed of the presentation of the smileys. Despite these variations, results were congruent across experiments. As expected, the presence of an experimenter did not affect performance in 5-year-olds. However, contrary to the predictions based on attentional capture hypothesis, performance in older children was similar across conditions, with evidence in favour of the absence of interaction between age and presence condition, despite the expected better performance in older compared to younger children. These results departed from what was observed in adults and have implications for understanding the audience effect.

The presence of an audience can impact our performance in tasks relying on executive functions. Even, the presence of a single person is enough to observe such an effect. It has been evidenced in adults' executive functions such as inhibition, switching or working memory (WM). However, investigations are still lacking in children. This is particularly important as such an effect can be detrimental and as children constantly experience audience, probably more than adults, when they are in classrooms (teachers), during their leisure activities (with at least one care giver around them) or in psychological assessment (e.g., in face of a school psychologist). Hence, the present study tested for the first time whether children's WM is impaired by the minimal audience that is the presence of a single adult. We chose to focus on this executive function because WM, which allows the short-term maintenance and processing of

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information, is of primary importance for cognitive development and academic achievement (Bayliss et al., 2003; Pickering, 2006; Swanson, 2008), and because no previous study examined the social presence effect in children's WM, despite evidence of a detrimental presence effect in adults' WM. Moreover, we chose to examine the presence of a single person, because previous studies showed that this minimal audience is already sufficient to impair executive functions in adults. This also represents a frequent situation in childhood.

1. Theoretical accounts of the audience effect

In the audience paradigm, the performance of individuals performing alone is compared with the performance of individuals performing while being in front of other individuals who can be viewed as simple spectators. The first evidence accumulated for more than a century (e.g., Mayer, 1903; Schmidt, 1904; Triplett, 1898) using this paradigm showed that the presence of others improves performance on easy or well learned tasks, and impairs performance on difficult or poorly learned tasks; two phenomena traditionally referred to as social facilitation/impairment effects (Bond & Titus, 1983; Geen & Gange, 1977; Guerin, 1993, for reviews). For a long time, the dominant theory (Zajonc, 1965) was that the presence of others increases drive (conceived as physiological arousal) and energises the emission of dominant responses (those with the greatest habit strength), which are often correct in easy tasks (leading to social facilitation), but incorrect in difficult tasks (leading to social impairment).

However, recent work does not support this dichotomy anymore with, for example, the performance of some complex tasks being facilitated in the context of an audience (e.g., Stroop Task: Huguet et al., 1999), and deteriorated for other tasks (e.g., Simon Task: Belletier et al., 2015). This discrepancy probably indicates that more complex processes take place in social presence conditions. Moreover, the fact that humans generally suffer from social presence on tasks requiring the inhibition of dominant responses suggests that social presence captures attention and undermines executive functions, which in turn impair performance on difficult tasks (Baron, 1986; Belletier et al., 2019a; Huguet et al., 2014; Wagstaff et al., 2008).

Baron (1986) reviewed findings indicating that audience may distract attention away from the task at hand, which in turn may threaten the organism with cognitive overload at least on attention demanding tasks. Interestingly, attention focusing may produce just the task effects usually viewed as evidence of drive: performance facilitation (by screening out nonessential stimuli) when the task is simple, and performance impairment (by neglecting crucial stimuli) when the task is more complex or demands attention to a wide range of cues.

2. Audience effect in executive functions

Huguet et al. (1999) were the first to test Baron's (1986) hypothesis against drive theory using the same design in a series of experiments with the Stroop task. Consistent with Baron's (1986) attentional account, Huguet et al. (1999) found a reduction of the Stroop effect under social presence conditions (compared to social isolation), especially when the presence of a single person (a peer confederate) seemed relatively attentive to the participant (looking at them 60 % of the time during task performance) (see also Dumas et al., 2005, for similar findings). Other results confirmed a significant reduction of the Stroop effect in the presence of a relatively attentive other (Augustinova & Ferrand, 2012; Huguet et al., 2004; Klauer et al., 2008; Sharma et al., 2010). Finally, studies using other inhibition tasks than Stroop task provided further evidence that the audience of a single person can distract attention away from the task (Normand et al., 2014).

However, inhibition is not the only executive function impaired by audience effect, and additional works have shown that the presence of a single person can actually hinder other executive functions. Wagstaff et al. (2008) tested this effect on switching with a verbal fluency task. In their first experiment, participants in the presence group produced fewer switches than participants in the alone condition, suggesting that switching was hindered by the social presence, probably because this presence captured attention as proposed by Baron (1986). Examining another executive function, namely WM, Belletier and Camos (2018) reported that the experimenter presence also hinders recall performance in a complex span task (in which participants maintained information while performing a secondary task). However, the detrimental effect on WM performance appeared only when the secondary task blocked the use of articulatory rehearsal, with no effect when participant can use articulatory rehearsal. This modulation of the audience effect on WM was interpreted by the authors as additional evidence in favour of Baron's attentional account of audience effect. To maintain verbal information in WM, two main maintenance mechanisms have been depicted, articulatory rehearsal and attentional refreshing (see Camos, 2015, for a review). While the former mechanism weakly relies on attention, the latter is an attention-demanding mechanism that reactivates memory traces in WM by refocusing attention to the traces. Adults can use both mechanisms concurrently. However, a concurrent articulation can block rehearsal and call for the use the remaining attentional refreshing. Accordingly, Belletier and Camos (2018) suggest that blocking rehearsal promotes the use of this alternative attentional mechanism, which led to the detrimental impact of the audience on recall. Overall, evidence has been gathered that the detrimental effect of the presence of a single person is generalised in what is commonly considered as the three main executive functions (inhibition, switching and WM). However, findings have been only collected in adults, and we are still lacking of research with children, although the field started by studying children.

Indeed, among the first investigations regarding the social presence effect, several were carried out in children aged from 8 to 14 years (Mayer, 1903; Schmidt, 1904; Triplett, 1898). Despite the early start of research in children, studies in children's executive functions are still scarce. To our knowledge, some recent studies examined the audience effect in children, but only one study focused on this effect in children's cognitive control.[1] For example, Arterberry et al. (2007) showed that children aged 5 years performed a simple puzzle better in the presence of one other child doing the same task than children doing the puzzle alone. However, performance in a hard puzzle did not differ across conditions. Tricoche et al. (2021) showed that cognitive tasks involving numerosity and phonological comparisons were performed better in the presence of another child in 8- and 10-year-old children. Concerning specifically the effect of experimenter presence in children's cognitive control, Frick et al. (2025) tested 5- and 9-year-old children with the AX-CPT task, which aims to assess the mode (reactive vs proactive) of cognitive control. The authors found that cognitive control and the use of proactive control (the most advanced mode of control) were reduced in the two age groups in the presence of an experimenter compared to a situation in which the child was alone. These results are in agreement with the findings in adults that executive functions are impaired by the presence of a single person. However, and contrary to the state of science in adults, no study tested whether an executive function can be impacted by this presence and whether this is modulated by age.

3. The present study

The aim of the present study was to explore the effect of the presence of an experimenter in children by focusing on one executive function, WM. Evidence supports the detrimental impact of this presence in adults' WM, but only under the use of attentional maintenance mechanism. From a developmental perspective, it has been shown that this mechanism appears after the age of 7 (Barrouillet et al., 2009; Camos & Barrouillet, 2011; Tam et al., 2010). While children aged between 7 and 14 are sensitive to a concurrent attentional demand that impairs their WM recall performance, recall in younger children, aged 5, is not affected by variations in concurrent attentional demand. Thus, 5-year-olds seemed to maintain verbal information without using attention. Moreover, although articulatory rehearsal is the default strategy to maintain verbal information in WM, when it is impaired by a concurrent articulation, children older than 7 use attentional refreshing for WM maintenance (Oftinger & Camos, 2018). As a consequence, it can be expected that WM should be impaired by the presence of an experimenter in children older than 7, similarly as in adults, but not in younger children. Hence, the present study tested this prediction by comparing 5- to 8-year-old children in a complex span task.

In a first experiment, we sought to assess the impact of the presence of an experimenter in 5- and 8-year-old children's WM. For this purpose, the presence or absence of an adult was manipulated between participants in each age group. In the presence condition, the experimenter stayed with the child during all the experiment, while the child remained alone in the room when performing the task in the isolation condition. The impact of the adult presence was measured using a complex span task in which children were asked to memorise auditorily presented words while performing a concurrent task. In order to support children's encoding, each word was simultaneously presented with an image; encoding being therefore auditory and visual to strengthen the memory traces and assure that age difference was not only due to deficit of encoding in the younger children. The secondary task in the complex span task was a colour-naming task using single-coloured smileys. This task requires to know only the names of the basic colours, which is acquired before the age of our younger participants. It was previously used in different studies with young children (Barrouillet et al., 2009; Camos & Barrouillet, 2011; Gimbert et al., 2016, 2019). Finally, its aim was twofold. First, as in any complex span tasks, the secondary task introduces a distraction that calls for an active maintenance of information. Second, this particular secondary task induces a concurrent articulation to name of each smiley's colours, which disrupts articulatory rehearsal. This constitutes the best condition to prevent the use of articulatory rehearsal and to promote the use of attentional refreshing. In Experiment 1, memory performance was tested through a recognition test, children choosing among different pictures the ones that were presented.

Because previous evidence showed that WM maintenance is not relying on attention in young children, children in our younger group should not be sensitive to the presence of an adult. We therefore expected that memory performance in 5-year-old children would be similar in the presence or absence of the experimenter. Young children could even benefit from the presence of the adult, as it can provide some motivation to perform at their best. However, unlike the younger group, children aged 8 should be able to implement attentional refreshing (Barrouillet et al., 2009; Camos & Barrouillet, 2011; Oftinger & Camos, 2016, 2018). Hence, according to Baron's (1986) account and to previous findings in adults, we expected poorer memory performance in the presence compared to in the absence of the experimenter in older children, because attention (or at least a part of it) would be captured by the presence of the experimenter.

The second experiment aimed at testing the same predictions by introducing a change in the memory test. Performance in recognition tests can rely on episodic memory and not so on the maintenance of memory traces in WM. To encourage maintenance in WM, we tested memory performance through an oral recall test. Finally, Experiment 3 tested older children, aged 8 and 11, in a complex span task for which the secondary task was more difficult. Without revealing the results of the previous experiments, involving older children assured us that our participants are old enough for using attentional refreshing. Moreover, the new secondary task would more strongly impair articulatory rehearsal, and thus help promoting attentional refreshing. These two changes should better reveal the impact of an audience on WM if audience captures attention.

[1] Cognitive control is an umbrella term that refers to all executive functions (Diamond, 2013).

4. Experiment 1

In this first experiment, 5- and 8-year-old children performed a complex span task either in the presence of an adult (i.e., the experimenter) or alone. In the complex span task, they memorised words that were presented auditorily and visually by an image, while they named aloud a series of coloured smileys. The concurrent task aimed at impairing articulatory rehearsal to promote attentional refreshing. According to findings in adults, the presence of an adult would distract attention that is therefore not used for maintenance in WM. Hence, we predicted that older children known for using attentional maintenance mechanism would present a similar effect as adults, and their memory performance would be reduced by the presence of an experimenter. On the contrary, younger children who do not use attentional refreshing and are not sensitive to concurrent attentional demand should not show such detrimental effect in memory performance. It can even be envisioned that the presence of an adult may be a motivation to remain attentive to the task for such young children, which may lead to improved memory performance in the presence of the experimenter.

5. Method

5.1. Participants

A total of 96 children[2] enroled in first and third grade of compulsory education in XX and having a parental or tutor authorisation participated in this study. Eight of them were excluded because of a diagnosed developmental disorder, a failure to follow instructions or a lack of understanding of the instructions. The assignment of the participant between the two conditions (presence or isolation) was randomised. No reward was offered to them, participation being voluntary. Before data analysis, the data from three children (i.e., two 5-year-old children and one 8-year-old child) with a digit span diverging by two standard deviations (SDs) from the mean of their respective age group were discarded. Moreover, the data from four children (i.e., one 5-year-old child and three 8-year-old children) with performance at the secondary task diverging from two SDs from the mean of their age group were also discarded. Therefore, data analyses were performed on 81 children: 36 5-year-old children (20 males and 16 females, $M = 5;1$, $SD = 4$ months, 20 in presence and 16 in isolation) and 45 8-year-old children (24 males and 21 females, $M = 8;2$, $SD = 4$ months, 24 in presence and 21 in isolation).

The study was approved by the Internal Review Board of the department of psychology of University of X (IRB_431/274 R) and the department for public instruction (X) of X. In accordance with the ethical regulations, no information on children has been collected, except sex and date of birth provided by the schools based on state documents.

6. Material

Eighty-four French words corresponding to coloured images from the Snodgrass and Vanderwart's (1980) database and revisited by Rossion and Pourtois (2004) were used. The words had one to three syllables. The number of syllables has been controlled, so that the length of the words to memorise remained similar across trials. Each word was recorded through voice recording software by a female voice and presented simultaneously with its corresponding image during the encoding phase of the complex span task. Lists of word-image pairs were created in order to avoid visual and phonological similarities between memory items presented in the same series. Eighty-four additional images were used as lures for the recognition test (see Appendix). For the concurrent colour-naming task, three coloured (i.e., red, blue and yellow) smileys were created.

7. Procedure

Half of the participants in each age group was tested by one of the two female experimenters. Each child was individually tested for about twenty minutes in a dedicated room of their school. Experimenters were introduced to the entire class at the start of the testing in the school. Experimenters had no particular familiarity bond with the children (e.g., they did not play with them in the playground). Experimenters saw the children only for the purpose of the study. At the start of the testing session, they have done everything they can to make the children feel comfortable to participate.

At the start of each trial of the complex span task, the number of memory items (list lengths from 1 to 6) was simultaneously indicated visually (with a digit in the centre of the screen) and audibly by the computer voice. After the presentation of a ready signal (a cross) for 2000 ms followed by a 2000 ms Inter-Stimulus Interval (ISI), the first memory item was presented; the image appeared on screen simultaneously to the auditory presentation of its associated word. The image remained on screen for 2000 ms and was followed by two smileys sequentially presented for 2000 ms each. After the second smiley, the recognition test occurred for trials of length 1, or another memory item followed by 2 smileys was presented and so forth for trials of longer lengths. The recognition test was not limited in time. A series of images appeared on screen, including all target images and an equal number of lures. The computer voice prompted the child to touch one by one the images in their order of presentation. Hence, she heard "touch the first image you have seen", after touching an image "touch the second image you have seen" and so on until she touched as many images as memory items presented in the trial. During the recognition test, all the images remained on screen until the child finished responding.

[2] Due to the absence of previous studies, our study being the first one to test the presence effect in children's working memory, we had no prior data to perform a G-power analysis. We then used a rule of thumbs of 40 children per age groups and decided to perform Bayesian analyses to test the plausibility of H1 and H0.

Trials were presented in increasing list lengths with four trials per length. The order of memory items and smileys was identical across participants. The experiment ended when the child failed in the four trials of the same length. A trial was scored correct when all memory items were correctly recognised in their order of presentation.

According to the condition in which the child was randomly assigned, the experimenter left the room (isolation condition) after the training phase, saying that she "had things to do and would come back later", or took a seat in a nearby chair (presence condition). In this latter condition, the experimenter was sitting about 150 cm, diagonally from the child at the other end of the table (Fig. 1). She directed her gaze for approximatively 40 % of the time to a book and 60 % to the child, without being able to see the computer screen. This procedure was successfully implemented in previous studies examining presence effects (e.g., Belletier et al., 2015; Huguet et al., 1999) and already proved to be effective to impact adults' WM (Belletier & Camos, 2018). In the isolation condition, a hidden audio baby monitor allowed experimenters to control what happened in the room for safety reasons, children being unaware of this control. (Fig. 2)

Before starting the experiment *per se*, a four-stage training phase took place, each stage presented as a game. Regardless of the presence condition, the experimenter remained in the testing room, seated side by side with each child in front of the computer screen throughout the entire training phases to ensure that the training was well done. In the training phase, children were first asked to name, without time limit, the colour of three smileys (one for each colour) appearing sequentially on the screen to check the ability to discriminate colours and assess knowledge of colour names. In case of errors, the experimenter corrected them. The second task was the same except that four smileys were sequentially presented, following the number and pace of a complex span task trial in which no memory items were presented. Hence, the naming of the colour was under time limit, with 2000 ms to respond to each smiley. After these two training stages, children were introduced to the memory task with two trials of the complex span task in which the smileys were absent and the memory items were well-known cartoon characters. Two trials were presented with one and two memory items, respectively. In case of error, children were corrected. Finally, they completed three trials of the complex span task (Fig. 2). Two trials included one and two cartoon characters as memory items and a final trial presented two memory items belonging to the pool of items used in the experiment.

The training phase and experiment were presented on a Microsoft Surface Pro tablet programmed using E-prime software (Psychology Software Tools, Pittsburgh, PA). Oral responses to the concurrent task were recorded through a Serial Response Box (SRBox). Finally, WM capacity was assessed with the digit span subtest of the Wechsler Intelligence Scale for Children (WISC; Wechsler, 2016) to check that children randomly assigned to the two conditions did not differ.

8. Results

All analyses were performed with JASP version 0.16.4 (JASP Team, 2024). Instead of reporting p values as in frequentists analyses, we used Bayesian statistics and reported Bayes Factors (BFs) for all analyses to overcome some of the shortcomings associated with null-hypothesis significance testing (Wagenmakers, 2007). For each dependent variable, a Bayesian Analysis of Variance (ANOVA) was performed using the default settings due to the absence of any preliminary studies on this topic in children. The BF_{10} of each model (e.g., main effects only, additive model, and main effects + interaction effects) was obtained by comparing it to the null model. For each dependent variable, we first report the best model, i.e., the model with the largest BF_{10}. Then, we report the $BF_{inclusion}$ value for each factor in the model (i.e., a main effect or an interaction effect), which indicates the likelihood of the data under models that included a given factor compared to all models stripped of the factor. A BF of 3 or more is considered substantial evidence for the model of interest, a BF below one third is considered substantial evidence for the null model and values around 1 indicate no substantial evidence either way (Dienes, 2014; Jeffreys, 1961). Similarly, we favoured the best model when its probability to account for the data

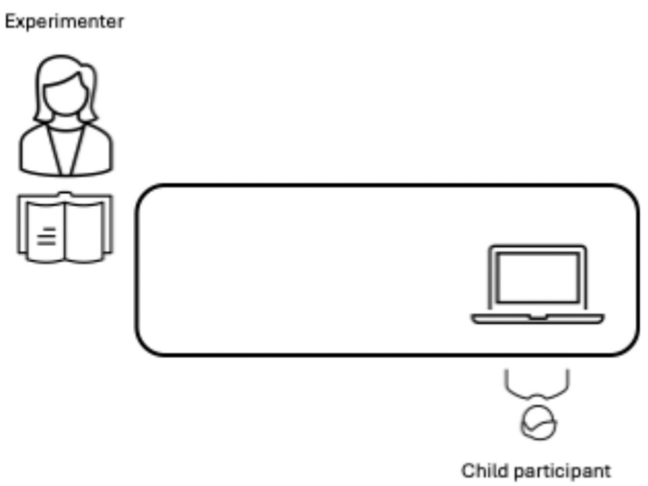

Fig. 1. Schematic representation of the location of the experimenter and the child participant during testing.

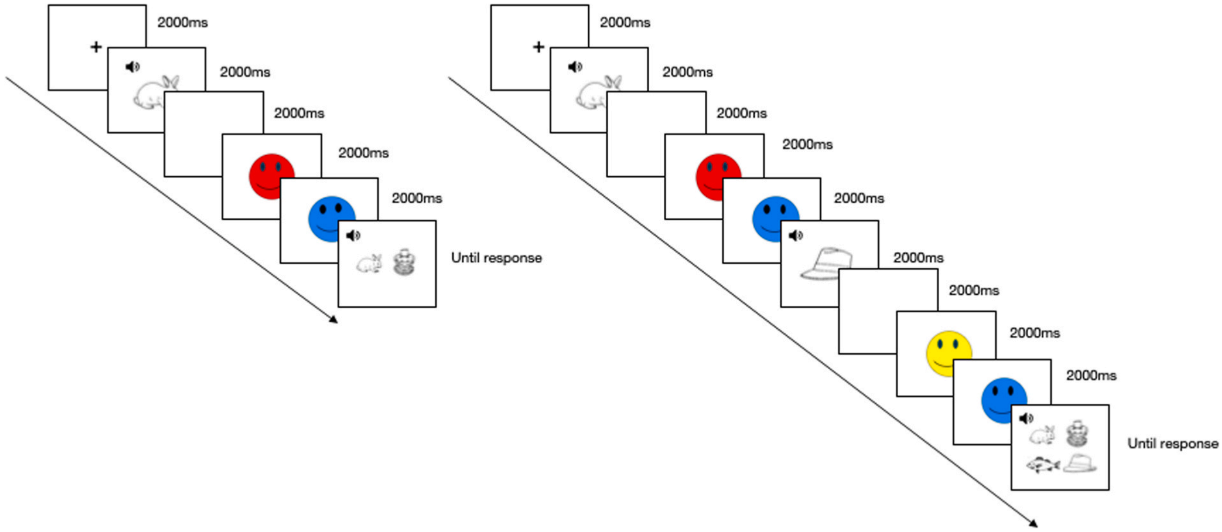

Fig. 2. Illustration of trials of Length 1 with one memory item (right) and of Length 2 with two memory items (left) of the complex span task used in Experiment 1. In the experiments, the pictures were in coloured images.

was 3 times greater than the second-best model; otherwise, both models were taken into consideration, and the examination of the $BF_{inclusion}$ of the effects included in the models helped choosing the model to favour.

9. Digit span task

To verify that children randomly assigned to the two experimental conditions did not differ on WM capacity, a Bayesian ANOVA was performed on digit span with condition (presence vs isolation) and age as between-subjects factors. The experimenter was introduced as a random factor. The best model involved only a main effect of age, $BF_{10} = 3.76x10^8$. As expected, 5-year-old children ($M = 4.72$, $SD = 1.49$) exhibited a lower digit span than 8-year-old children ($M = 7.49$, $SD = 1.65$). This model was 2.97 times preferred to the second-best model that included the main effects of age and condition, $BF_{10} = 1.31 \times 10^8$. However, evidence weakly supported the main effect of the condition, $BF_{inclusion} = 0.36$. Children who performed the experiment in the presence of an adult had similar digit span ($M = 6.07$, $SD = 1.98$) to those of children who performed the experiment alone ($M = 6.49$, $SD = 2.22$). No support was gathered in favour of an interaction, $BF_{inclusion} = 0.63$.

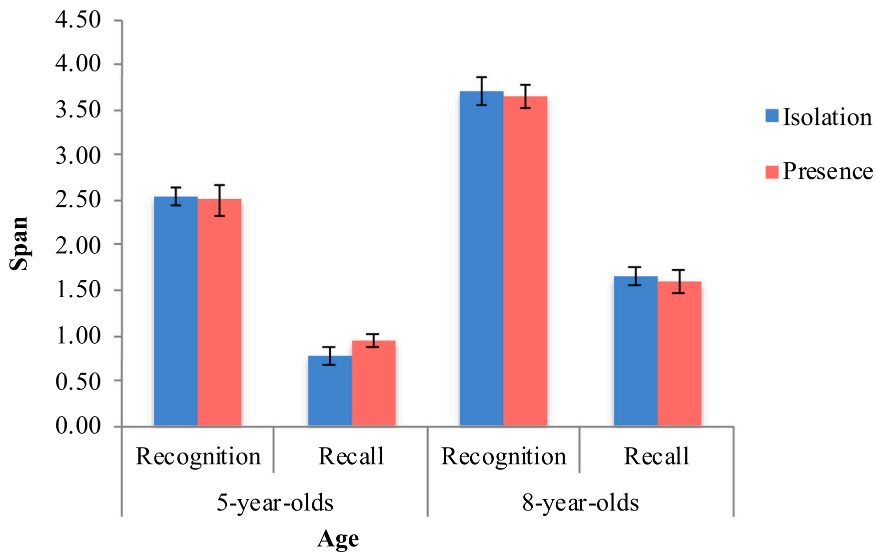

Fig. 3. Mean span in 5- and 8-year-old children according to the isolation or presence condition in Experiments 1 (serial recognition test) and 2 (serial oral recall test). Bars represent standard errors.

10. Colour naming task

A Bayesian ANOVA with the same design was performed on the percentage of correct responses in the secondary task. The best model involved only a main age effect, $BF_{10} = 1.32 \times 10^4$. Eight-year-old children produced slightly more correct responses (*M* = 98.65, *SD* = 2.03) than 5-year-old children (*M* = 91.53, *SD* = 9.05), both age groups achieving a very high accuracy. This model was 3.28 times preferred to the additive model, $BF_{10} = 4.01 \times 10^3$. There was weak evidence for a difference between experimental conditions, $BF_{inclusion} = 0.31$ and no support for the interaction, $BF_{inclusion} = 0.35$. Children in the presence of the experimenter performed the concurrent task as well (*M* = 94.89, *SD* = 7.01) as the children who were alone in the room (*M* = 96.20, *SD* = 7.30). These high accuracy rates assured us that both age groups understood the instructions and tried their best in solving the colour naming task.

11. Memory performance in the complex span task

To evaluate the impact of the experimenter's presence and children's age on WM performance (Fig. 3), we analysed several indexes. First as in most recognition tasks, we computed the rate of hits, i.e., the number of correct recognitions. We do not report analyses on false alarms, because children had to make a choice of image for every position in our experimental procedure, the rate of false alarms was then equal to 1 – hit rate. The best model of the Bayesian ANOVA performed on the hit rate with the same design as the previous ANOVAs included only a main effect of age, $BF_{10} = 2.73 \times 10^6$, and was 3.9 times preferred to the additive model, $BF_{10} = 7.05 \times 10^5$. The mean rate of hits was higher in 8-year-old (*M* = .73, *SD* = .08) than 5-year-old children (*M* = .58, *SD* = 0.12). Evidence was gathered for the absence of an effect of the condition, $BF_{inclusion} = 0.26$, the children in presence (*M* = .65, *SD* = .14) exhibiting similar hit rate than those in isolation (*M* = .67, *SD* = .11). No evidence supported the interaction, $BF_{inclusion} = 0.33$.

Second, for sake of comparisons with the following experiments, we calculated the span of each child. The span corresponded to ¼ x N, N being the number of correctly recalled trials. To be scored as correct, all memory items in a trial had to be recognised in their correct serial position. The findings on span were similar to those on the rate of hits. The best model of the Bayesian ANOVA performed on span with the same design of the previous one included only a main effect of age, $BF_{10} = 3.63 \times 10^8$ (Fig. 3), and was preferred 4.1 times to the additive model, $BF_{10} = 8.77 \times 10^7$. As expected, the mean span was higher in 8-year-old (*M* = 3.68, *SD* = 0.67) than 5-year-old children (*M* = 2.51, *SD* = 0.65). Evidence was gathered for the absence of an effect of the condition, $BF_{inclusion} = 0.24$ and of the interaction, $BF_{inclusion} = 0.29$. The performance of the presence group (*M* = 3.13, *SD* = 0.92) was similar to that of the isolation group (*M* = 3.20, *SD* = 0.84).

Finally, although it is not systematically analysed in WM task (although for some exceptions, see Cowan et al., 1992; Rosselet-Jordan et al., 2022), the type of response used in this experiment (by pointing to an image) allowed to easily collect the speed of responses. This analyse aimed to check whether the presence of an experimenter affected speed of responses, even if accuracy was not impacted. We analysed these response times for all answers and when answers were correct. Bayesian analyses with the same design as the two previous ones were performed on the speed of responses. When all answers were included, none of the examined models (i.e., models with one main effect, additive model and the full model) were supported, $BF_{01} < .31$, and the evidence supported an absence of the main effects, $BFs_{inclusion} < .31$, and did not support interaction $BF_{inclusion} = .66$. When only the correct answers were taken into account, the pattern of findings was similar to what was reported for the rate of hits and span, the best model included only the main effect of age, $BF_{10} = 14.11$; older children being faster to respond (*M* = 3130 ms, *SD* = 506) than the younger (*M* = 3551 ms, *SD* = 689). This model was preferred 4.0 times to the additive model., $BF_{10} = 3.53$. Evidence was gathered for the absence of an effect of the condition, $BF_{inclusion} = 0.25$, the children in presence (*M* = 3333 ms, *SD* = 538) exhibiting similar hit rate than those in isolation (*M* = 3299 ms, *SD* = 726). No evidence supported the interaction, $BF_{inclusion} = 0.72$.

12. Discussion

In this experiment, the pattern of findings was very congruent across the indexes we analysed. First, we confirmed the expected age effect, with older children outperforming the younger in memory performance and being faster to respond. More importantly for the purpose of the study, we expected that memory performance in 5-year-old children would not be impacted by the presence of the adult. Our results supported this hypothesis. In 5-year-olds, the presence group did not differ from the isolation group on memory performance assessed through a recognition test. However, and contrary to our predictions, we found no evidence in favour of the predicted interaction with age. Span in 8-year-old was similar across conditions, as it was observed in the younger children. These results showed that memory performance was not affected by the presence of an adult, similarly in 5- and 8-year-old children.

Nevertheless, it should be noted that participant's memory performance was rather high and many children were able to reach lengths five and six (42 % in 5-year-olds and 89 % in 8-year-olds), lengths that are often considered as exceeding WM capacity (Cowan, 2010; Unsworth & Engle, 2007). According to Unsworth and Engle (2007), once this capacity is reached, items can no longer be retained in WM (primary memory) and must be moved to long-term memory (LTM; secondary memory), from where they are retrieved for the memory test. These findings suggest that the recognition test implemented in this experiment might not have required WM maintenance. The use of a simple process of familiarity, a feeling of *déjà-vu*, based on LTM memory traces would be enough to achieve such a recognition test. Some evidence supported this assumption in adults, showing that recall tasks are more accurate at identifying effects on WM maintenance (Uittenhove et al., 2019). Hence, in order to assess whether the current findings depend on the recognition test, we performed a second experiment in which WM performance was assessed through a recall test.

13. Experiment 2

This second experiment tested the same predictions as Experiment 1 with a similar design, except that the recognition test in Experiment 1 was replaced by an oral recall test.

14. Method

14.1. Participants

Ninety-eight children enroled in the compulsory education system participated in this study with parental or tutor authorisation. Ten participants were excluded from our sample because of a developmental disorder, a failure to follow instructions or a lack of understanding of the task. The assignment of participant between the two conditions (presence or isolation) was randomised. Participation in the study was voluntary and no reward or compensation was offered to the participants. None of these children participated to the first experiment. As we did in Experiment 1, the data from six children (i.e., four 5-year-olds and two 8-year-olds) with a digit span diverging from 2 SDs from the mean of their respective age group were discarded. Moreover, the data from four children (i.e., three 5-year-olds and one 8-year-old) with performance in the secondary task diverging from 2 SDs from the mean of their age group were also discarded. The data analyses were thus performed on 78 children: 32 5-year-old children (16 males and 16 females, $M = 4;11$, $SD = 4$ months, 18 in presence and 14 in isolation) and 46 8-year-old children (24 males and 22 females, $M = 7;11$, $SD = 4$ months, 22 in presence and 24 in isolation).

15. Material and procedure

The materiel and procedure were similar to Experiment 1 (Fig. 1 & 2), with the exception of two changes. The first concerned the memory test in which children were asked to recall aloud the memory items one after the other in their order of presentation. In case of omission, the child had been taught to say, "Je ne sais pas" (I don't know). To help children, question marks with vocal instructions were presented on the screen for each to-be-recalled item. The second change was the adaptation of the stop rule. Because order was difficult to understand for the younger children and could lead to underestimating their memory performance, the stop rule did not take order errors into account for both age groups. A series was considered false only if omissions or intrusions were made.

16. Results

We implemented the same data analysis as in Experiment 1.

17. Digit span

To verify that our two groups were equivalent in terms of WM capacity, a Bayesian ANOVA was performed on digit span with age and condition as between-subject factors, and experimenters as a random factor. The best model included only a main effect of age, $BF_{10} = 1.43e + 6$, and was 4.36 times preferred to the additive model, $BF_{10} = 3.29 \times 10^5$. Eight-year-old children had higher digit span ($M = 6.65$, $SD = 1.62$) than 5-year-old children ($M = 4.63$, $SD = 0.91$). Evidence of an absence of a main effect of the condition was substantial, $BF_{inclusion} = 0.23$ and the interaction was not supported, $BF_{inclusion} = 0.50$. Children assigned to the presence condition obtained a similar digit span ($M = 5.73$, $SD = 1.65$) to those assigned to the isolation condition ($M = 5.92$, $SD = 1.76$).

18. Colour-naming task

A Bayesian ANOVA with the same design as the previous one was performed on the percentage of correct responses in the concurrent task. The best model was the additive model including the two main effects of age and condition, $BF_{10} = 5.98$. It was 1.20 times preferred to the second model, which included the main effect of age, $BF_{10} = 4.97$. The examination of the $BFs_{inclusion}$ favoured the latter model, because the value of the $BF_{inclusion}$ for the main effect of age was the only one superior to 3, $BF_{inclusion} = 5.93$. Performance on the concurrent task was very high in both age group ($M = 94.14$, $SD = 6.53$ in 5-year-olds and $M = 97.15$, $SD = 3.61$ in 8-year-olds). Besides this effect, the main effect of the condition, $BF_{inclusion} = 1.14$, and the interaction, $BF_{inclusion} = 0.48$, were not supported. Children in the presence of the experimenter ($M = 96.91$, $SD = 4.15$) as well as alone in the room ($M = 94.88$, $SD = 5.99$) named correctly a high percentage of smileys.

19. Memory performance in the complex span task

First, we performed a Bayesian ANOVA on the span calculated as in Experiment 1 (i.e., order being taken into account) (Fig. 3). The best model involved only a main effect of age, $BF_{10} = 8.15 \times 10^6$, and preferred 4.65 times to the additive model, $BF_{10} = 1.75 \times 10^6$. As it can be expected, the mean span in 8-year-old children was higher ($M = 1.62$, $SD = 0.54$) than in 5-year-old children. ($M = 0.88$, $SD = 0.34$). Evidence was gathered for the absence of an effect of the condition, $BF_{inclusion} = 0.22$, with no support for the interaction, $BF_{inclusion} = 0.55$. The average performance of the presence group ($M = 1.31$ $SD = 0.50$) was very similar to that of the isolation group ($M = 1.33$, $SD = 0.70$).

Second, a similar analysis was performed on a span measure that did not take into account the order, as order can be difficult to understand by the younger children. It led to similar findings. The best model included the main effect of age only, $BF_{10} = 4.03 \times 10^6$, with the 8-year-olds having higher span than the 5-year-old children ($M = 1.63$, $SD = 0.54$ vs. $M = 0.89$, $SD = 0.34$). This model was 3.87 times preferred to the additive model, $BF_{10} = 1.04 \times 10^6$. Evidence was gathered for the absence of an effect of the condition, $BF_{inclusion} = 0.26$ ($M_{presence} = 1.33$, $SD = 0.50$ vs. $M_{isolation} = 1.33$, $SD = 0.68$) and do not support the interaction, $BF_{inclusion} = 0.49$.

Finally, it should be noted that scoring memory performance in terms of percentage of correct responses (with or without taking order into account) led to similar patterns of findings: the best model including the sole main effect of age, $BF_{10} = 1.25 \times 10^8$ and $BF_{10} = 1.20 \times 10^7$, respectively. Evidence supported the absence of effect of the condition, $BFs_{inclusion} = .25$ and.28, and of the interaction, $BFs_{inclusion} = .33$ and.30, respectively.

20. Discussion

Compared to the recognition test in Experiment 1, memory performance assessed through a recall task in Experiment 2 was lower in the two age groups (Fig. 3). This difference was supported by a $BF_{inclusion} = 5.15 \times 10^{41}$ when memory performance (scored as span with order as depicted in Fig. 2) was compared between experiments in a Bayesian ANOVA. Contrasting with this finding, it should be noted that, children were comparable across experiments on their WM capacity assessed by the digit span, the BF for the experiment being inferior to 3, $BF_{inclusion} = 1.55$, and that no evidence was gathered for an interaction with the factor experiments, $BFs_{inclusion} < .69$. These results suggest that children did not use the same processes in both experiments. This variation hence created some differences in the raw level of memory performance, but did not modify the main pattern of findings. As in the first experiment, the effect of age was confirmed, with the 8-year-old children outperforming the younger ones, but once again, no evidence was gathered in favour of the effect of experimenter presence and its interaction with age. Results suggest that the presence of an adult does not affect WM performance in both age groups.

However, one can suggest that the secondary task we used may not be sufficient to impair the use of articulatory rehearsal in the older group of children. Indeed, to allow the performance by the younger children, the pace of the secondary task was relatively slow for 8-year-olds. It could be then envisioned that the older children surreptitiously rehearse some memory items in-between the naming of colours, with little (or no) use of attentional refreshing. Hence, in the last experiment, we increased the pace of the colour-naming task to reduce opportunities to rehearse. Moreover, as the use of refreshing emerges at 7, one may question whether 8-year-olds are using it to the point to be affected by a concurrent attentional capture. Against this argument, it should be noted that WM performance in 8-year-olds is hindered by the attentional demand of a secondary task (Barrouillet et al., 2009; Oftinger & Camos, 2016, 2018; Tam et al., 2010). However, this effect is smaller in 8-year-olds than in older children. Hence, we tested older children, aged 11, for whom attentional capture by a secondary task has a clear impairing effect on WM. This allowed us to test whether the absence of audience effect reported in Experiments 1 and 2 results from a misuse of refreshing or is a genuine effect in children.

21. Experiment 3

In this third experiment, the same predictions were tested in 8- and 11-year-old children who performed a similar complex span task as in the previous experiments, but in which the pace of the secondary task was increased to prevent articulatory rehearsal.

22. Method

22.1. Participants

A total of 100 (45 8-year-olds and 55 11-year-olds) children enroled in compulsory education in X and having a parental or tutor authorisation participated in this study. Five 8-year-olds and three 11-year-olds were excluded because of a diagnosed developmental disorder or a failure to follow instructions. The assignment of the participant between the two conditions (presence or isolation) was randomised. No reward was offered to them, participation being voluntary. Before data analysis, the data from two 8-year-old and three 11-year-old children with a digit span diverging from 2 SDs, as well as the data from two children in each age group with performance in the secondary task diverging from 2 SDs from the mean of their age group were discarded. The data analyses were thus performed on 36 (12 males and 24 females, $M = 7;11$, $SD = 5$ months; 19 in presence and 17 in isolation) 8-year-old children and 47 (23 males and 24 females, $M = 10;9$, $SD = 5$ months; 25 in presence and 22 in isolation) 11-year-old children.

23. Material and procedure

The procedure of Experiment 3 was similar to the second experiment, with five changes to adapt the material and procedure to older participants. First, the memory items were consonants (excluding “w”, which is trisyllabic in French, New et al., 2001) presented visually and auditorily. Lists were created in order to avoid repetitions and acronyms, and to have 4–5 occurrences of each letter across the experiment. Second, the presentation of each memory item was reduced to 1500 ms with a 500 ms ISI. Third, for the concurrent task, eight different colours were used: yellow, orange, red, pink, purple, blue, green, and grey, and three smileys were sequentially presented during 1500 ms each in the inter-letter intervals. Fourth, oral recall was prompted by a voice instruction (e.g., "Say in order the two letters you saw "). Once the recall was completed, the child was asked to press the "space bar" to proceed to the next trial. Finally, the list length was increased to 7, but with 3 trials per length (instead of 4 in the previous experiments) to keep the duration of the testing similar to the previous experiments.

24. Results

24.1. Digit span

As in the two previous experiments, a Bayesian ANOVA was performed on the digit span with age (8 vs 11) and condition as between-subject factors and experimenter as random factor. For the digit span, the best model included only the main effect of age, $BF_{10} = 1.06 \times 10^3$, with 11-year-olds ($M = 8.06$, $SD = 1.45$) outperforming the 8-year-old children ($M = 6.56$, $SD = 1.63$). This model was 4.39 times preferred than the second-best model, which included age and condition, $BF_{10} = 2.41 \times 10^2$. Evidence supported the absence of a main effect of the condition, $BF_{inclusion} = 0.23$, and of the interaction, $BF_{inclusion} = 0.31$. Children assigned to the presence condition obtained a similar digit span ($M = 7.43$, $SD = 1.68$) than those who performed the experiment in the isolation condition ($M = 7.38$, $SD = 1.73$).

25. Colour-naming task

For the performance in the colour-naming task, the best model included the two main effects of age and condition, $BF_{10} = 1.25 \times 10^4$, the second-best model included only the main effect of age, $BF_{10} = 4.97 \times 10^3$ being only 2.51 times less preferred. In accordance, the evidence supported the main effect of the age, $BF_{inclusion} = 5.60 \times 10^3$ was stronger than for the effect of the condition, $BF_{inclusion} = 2.99$, the interaction being not supported, $BF_{inclusion} = 0.39$. It should be noted that children assigned to both conditions followed the instructions very well and reached a high level of accuracy ($M = 94.83$, $SD = 6.13$ in the presence condition vs. $M = 90.88$, $SD = 9.97$ in the isolation condition)

26. Memory performance in the complex span task

A Bayesian ANOVA with the same design as previously was performed on the memory span. In comparison to the two previous experiments, the computation of the span was adapted to the fact that only 3 trials were presented in each length (instead of 4 in the previous experiments). Hence, the span corresponded to $^1/_3$ x N, N being the number of correctly recalled trials (order being taken into account). The best model involved only a main effect of age, $BF_{10} = 3.87\text{x}10^4$, and preferred 4.71 times to the additive model with age and condition effects, $BF_{10} = 8.22 \times 10^3$. As it can be expected, the 11-year-old children ($M = 2.12$, $SD = 0.97$) outperformed the 8-year-old children ($M = 1.15$, $SD = 0.45$). Evidence was gathered for the absence of an effect of the condition, $BF_{inclusion} = 0.21$, with no support for the interaction, $BF_{inclusion} = 0.35$. The average performance of the presence group ($M = 1.73$ $SD = 0.97$) was very similar to that of the isolation group ($M = 1.66$, $SD = 0.87$).

Second, as in Experiment 2, we did similar analysis on a span measure that did not take into account the order. It led to similar findings. The best model included only the main effect of age, $BF_{10} = 1.35 \times 10^4$, with the 11-year-olds having higher span than the 8-year-old children ($M = 2.16$, $SD = 1.01$ vs. $M = 1.19$, $SD = 0.49$, respectively). This model was 3.93 times preferred to the additive model, $BF_{10} = 3.44 \times 10^3$. Evidence was gathered for the absence of the presence effect, $BF_{inclusion} = 0.25$ ($M_{presence} = 1.78$, $SD = 1.00$ vs. $M_{isolation} = 1.68$, $SD = 0.90$). Moreover, no evidence supported the interaction between presence condition and age, $BF_{inclusion} = 0.37$.

Finally, analysis on the percentage of correct responses confirmed these findings. The best model included the sole main effect of age, $BF_{10} = 5.64\text{x}10^4$ and $BF_{10} = 5.77 \times 10^4$, with and without taking order into account to compute the percentage of correct responses, respectively. Evidence did not support the effect of the condition, $BFs_{inclusion} = .38$ and.34, and was against the interaction, $BFs_{inclusion} = .30$ and.31, respectively.

27. Discussion

In this experiment, we implemented changes in the complex span task to make the task more difficult. This was confirmed when comparing 8-year-olds' performance across Experiments 2 and 3 with a Bayesian ANOVA, the BF for the factor experiment supported strongly the reduction of memory performance ($BF_{inclusion} = 5.57 \times 10^2$ in span, and $BF_{inclusion} = 1.19 \times 10^7$ in percentage of correctly recalled letters). It should be noted that the two samples of 8-year-old children enroled in these experiments were comparable in terms of digit span, $BF_{inclusion} = .27$.

Despite having a more difficult complex span task and enroled older children for which the use of attention to maintain information is WM is undoubtful, Experiment 3 confirmed the absence of audience effect in children's WM, contrary to what is observed in adults. Potential reasons for the difference between children and adults, as well as implications for the theoretical accounts of the audience effect are discussed in the general discussion.

28. General discussion

The aim of the present study was to assess the effect of the experimenter presence in children's WM. While in adults, evidence has been collected on the detrimental effect of this presence on different executive functions, studies in children are still lacking. WM being so clearly linked with cognitive development, learning and academic achievement, we focused on this executive function for this first attempt to test the experimenter presence effect in children's executive functions. In previous work, it has been reported that the detrimental effect of the experimenter presence occurs in adults when they rely on attention to maintain information in WM, but not when using articulatory rehearsal. This contrasted pattern of findings has been interpreted in favour of Baron's (1986) attentional account. According to this account, the presence captures attention, which is not anymore available for any attention-demanding mechanism (e.g., attentional refreshing in WM). Because attentional refreshing has been reported in children older than 7, a similar detrimental effect should be observed in older children when articulatory rehearsal is impaired. On the contrary, younger children who do not use attentional refreshing should not be affected by the presence of an adult while performing a WM task. Across three experiments, our findings were congruent and against any effect of the experimenter presence in children's WM, despite the fact that we varied the type of memory test (recognition and recall), the difficulty of the secondary task, the type of memory items (pictures or letters), and the age of our participants (5, 8 and 11). These findings lead to the question of what can drive this difference between adults and children, and whether Baron's attentional account is an adequate theory for understating the presence effect.

29. How to understand the difference between adults and children

As we mentioned in the discussion for Experiment 2, one can propose that children, contrary to adults, do not use attention at all for maintaining information in WM. This would surely account for the absence of effect in children. However, we think that it is very unlikely that children as old as 11 years of age would not use attentional refreshing. Barrouillet et al. (2009) have shown that varying the attentional demand of the secondary task has an impact on the recall performance, the reduction of performance being stronger as children are older (from 7 to 14 years of age). Other studies in children reported similar decline of performance with increased concurrent attentional demand (Oftinger & Camos, 2016, 2018; Tam, et al., 2010). It should also be noted that the complex span task implemented in the present study induces a concurrent articulation, which makes rehearsing (aloud or subvocally) the memory items difficult. Thus, it leaves little alternative to maintain information. As the memory items were presented visually and auditorily, children could have maintained them visually. However, the visual recapitulation of memory items would also require some attention, and thus it is difficult to understand why, if audience captures attention, this strategy would make children immune to the experimenter presence effect. A similar reasoning would stand for alternative maintenance mechanisms that rely on attention.

We suggest that the absence of effect may result from the lower WM capacity exhibited by children compared to adults. In a study providing evidence of a detrimental effect in the Simon task, Belletier et al. (2015) reported that performance in adults with higher WM capacity (WMC) was more impaired by the presence of an experimenter than in adults with lower WMC. Whereas higher WMC participants performed the Simon task clearly better than the lower WMC participants under isolation condition, they actually underperformed relative to their lower WMC counterparts in the presence of the experimenter (see Belletier et al., 2019a, for a similar result with another task measuring executive functions). In line with Engle (2002), Belletier et al. (2015) proposed that higher WMC individuals may be more able to attend simultaneously to the focal task and the presence of the experimenter because these individuals benefit from more attentional resources than other individuals. This would be done at the expense of task performance, at least on attention demanding tasks. When comparing children to adults, the latter having more WMC than the former, the audience effect should be stronger in adults than in children and be more difficult to observe in the latter. This is what we reported here. Hence, the lower WMC of children may have protected them from the detrimental effect (see Frick, 2024, for a similar suggestion). If it is the case, older adolescents (after 15 years of age) who have rather similar WMC than adults may then be sensitive to the presence effect. To our knowledge, no work ever examined the experimenter presence effect on any executive functions in adolescence. Although there are several studies on the audience effect in adolescents, they are mostly focused on risk-taking, and only few of them examined cognitive performance (see Bevington & Wishart, 1999; Wolf et al., 2015, for such exceptions). Further studies should then aim at testing this prediction in adolescents.

30. Do these findings challenge Baron's attentional account?

An alternative account is that these findings contradict Baron's attentional account of the audience effect. The fact that children old enough for using attention in WM maintenance (i.e., older than 7) and under condition that promotes the use of this mechanism do not exhibit the detrimental effect is at odds with predictions issued from Baron's account. Despite studies in the literature that support this account, can we consider that the alternative model, Zajonc's (1965) drive theory, may be a better explanation, at least for children? According to Zajonc's theory, an audience (of a single person or more people) should lead to performance improvements in simple tasks and impairments in complex tasks. It is difficult to consider that a complex span task, which requires the maintenance of information in WM while performing a secondary task (even as simple as naming colours), is a simple task. Dual-tasking is a well-recognised challenge for human cognitive system. As a consequence, even Zajonc' theory would also predict an impairment of performance in such a task. Our findings contradict also this theory.

Other theoretical explanations have been put forward to explain audience effects (see Guerin, 1993, for a review). Among them, the "mere effort theory" (Harkins, 2006) is sometimes cited as the main alternative to Baron's hypotheses. For Harkins (2006), in the presence of others, the efforts of individuals under evaluation would be centred on the "prepotent response", an expression that Harkins (2006) uses to designate the response with the highest probability of emission. Note that this concept is very similar to Zajonc's (1965) "dominant response". Harkins' hypothesis leads to the same expectations as Zajonc's, but it simply dispenses with the physiological activation mechanism inferred by the latter to explain social facilitation effects. McFall et al. (2009) complemented Harkins' (2006) theory by adding a notion of corrective effort. Individuals who realise that they are making errors would make more effort to correct them in the presence of other-s. This theory would therefore lead to predict an increase in performance in the presence of other-s as soon as children are able to consider that they are making mistakes (i.e., from age 3 onward according to Grammer et al., 2014).

Finally, one point that we did not address in this study is the type of experimenter's behaviour. Research in adults has shown, for example, that an experimenter does not have the same effect on performance on a WM measure depending on how the experimenter behaves (Nemeth et al., 2013). Recent work suggests that in a similar way, the familiarity and relationship between the experimenter and children could have a moderating influence on children's executive functions (Frick, 2024; Gidron et al., 2020). While it has been established that the threatening or evaluative nature of the presence plays a major role for adults (e.g., Belletier et al., 2019b; Feinberg & Aiello, 2010), some studies with children have documented how a familiar experimenter positively affects performance. For example, memory capacities in 5- to 7-year-olds during an eyewitness identification are improved in the presence of a familiar experimenter (Calderwood et al., 2023). Similarly, children are more motivated to make greater effort to maintain task goals if their performance is important to another individual, especially a familiar experimenter (Doebel, 2020). It can be suggested that the creation of familiarity bond between the children and the experimenters may also have a moderating effect on WM performance. Hence, beside studying the role of the threatening or evaluative nature of the presence as it was done in adults, future research with children should particularly aim at varying the familiarity of the children-experimenter relationships.

31. Conclusion

This first attempt to examine the experimenter presence effect in children's executive function led to opposite findings than in adults. Although developmental differences in WM capacity may explain this absence of detrimental effect in children, it is also rather reassuring to see that children are not impaired in the highest cognitive functions when an adult is around. This is such a frequent situation of any child. Nevertheless, the effect in children remains to be explore in other essential cognitive functions. Even though in adults, the presence of a single adult impacted in a similar way the different executive functions, specificities in the development of each of these functions may result on a different pattern in children. We hope that this study opens the systematic exploration of this effect in children's executive functions.

Appendix

For each picture, the table shows the identifying number in Snodgrass and Vanderwart (1980) database, the English name, the French name, the status in Experiment 1 (memory items or lures in the recognition test), the mean and standard deviation for the ratings of familiarity and complexity as reported originally in Snodgrass and Vanderwart (1980).

Number	English name	French name	Status	Familiarity		Complexity	
				Mean	SD	Mean	SD
2	Airplane	avion	memory	2.15	1.20	4.68	0.61
4	Anchor	ancre	lure	1.60	0.83	2.58	0.70
5	Ant	fourmi	memory	2.62	1.11	3.92	0.82
6	Apple	pomme	memory	3.98	1.08	1.82	0.67
8	Arrow	flèche	memory	3.38	1.23	1.05	0.31
12	Axe	hache	memory	2.28	1.10	2.48	0.74
13	Baby carriage	poussette	memory	2.72	1.14	3.42	0.10
15	Balloon	ballon	lure	2.58	1.02	1.55	0.59
16	Banana	banane	memory	3.65	1.04	1.32	0.47
20	Basket	panier	lure	2.18	0.97	4.30	0.84
21	Bear	ours	lure	1.98	1.01	3.68	0.90
22	Bed	lit	lure	4.73	0.77	2.85	0.79
25	Bell	cloche	memory	2.20	0.93	2.62	0.66
26	Belt	ceinture	lure	4.12	1.05	2.00	0.59
27	Bicycle	vélo	memory	3.78	1.04	3.85	0.11
28	Bird	oiseau	memory	3.62	1.16	3.25	0.73
30	Book	livre	memory	4.75	0.54	2.10	0.66
31	Boot	botte	memory	3.38	1.24	2.45	0.70
32	Bottle	bouteille	memory	3.72	1.05	1.68	0.79
33	Bow	nœud	lure	2.25	1.18	2.75	0.86
34	Bowl	bol	lure	4.18	0.92	1.82	0.80
36	Bread	pain	memory	4.40	0.83	1.95	0.67
37	Broom	balai	memory	3.42	1.14	2.42	0.80
38	Brush	brosse	lure	3.80	1.08	2.82	0.74
39	Bus	bus	memory	4.50	0.74	3.95	0.10
40	Butterfly	papillon	lure	2.92	1.17	4.25	0.77
41	Button	bouton	memory	3.85	1.26	2.02	0.76
42	Cake	gâteau	lure	4.02	1.06	2.88	0.68
44	Candle	bougie	lure	3.08	1.15	2.48	0.90
45	Cannon	canon	memory	1.52	0.63	3.92	0.82
47	Car	voiture	lure	4.70	0.60	4.05	0.95
48	Carrot	carotte	memory	3.55	0.97	2.95	0.77
49	Cat	chat	memory	4.22	0.88	3.25	0.94
52	Chain	chaîne	memory	2.82	1.00	2.55	0.97
53	Chair	chaise	lure	4.58	0.86	2.05	0.70
54	Cherry	cerise	lure	3.38	1.18	1.60	0.62

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(*continued*)

55	Chicken	poule	lure	2.42	1.09	3.48	0.90
62	Cloud	nuage	memory	3.82	1.19	2.12	0.87
63	Clown	clown	lure	2.60	1.16	4.50	0.81
65	Comb	peigne	lure	4.52	0.87	2.38	0.83
66	Corn	maïs	memory	3.50	1.05	3.58	0.86
67	Couch	canapé	memory	4.40	0.74	2.28	0.84
68	Cow	vache	memory	2.42	1.20	3.85	0.96
69	Crown	couronne	lure	1.52	0.81	4.25	0.77
70	Cup	tasse	lure	4.40	0.83	1.78	0.52
71	Deer	cerf	memory	2.22	1.21	3.55	0.77
72	Desk	bureau	lure	4.32	0.90	3.05	0.84
73	Dog	chien	lure	4.60	0.70	3.38	0.73
74	Doll	poupée	memory	2.92	1.14	4.12	0.93
75	Donkey	âne	memory	1.88	0.87	3.35	0.69
76	Door	porte	lure	4.68	0.79	3.22	0.69
78	Dress	robe	lure	3.62	1.46	2.65	0.65
80	Drum	tambour	memory	2.60	1.16	2.88	0.75
81	Duck	canard	lure	2.75	1.11	3.32	0.82
83	Ear	oreille	lure	4.50	0.70	2.68	0.82
84	Elephant	éléphant	lure	2.35	1.04	4.12	0.78
86	Eye	œil	memory	4.88	0.40	3.48	1.10
88	Finger	doigt	lure	4.78	0.79	2.30	0.95
89	fish	poisson	lure	3.28	1.22	3.75	1.02
90	Flag	drapeau	memory	2.90	1.28	1.88	0.46
91	Flower	fleur	lure	3.88	1.19	3.25	0.94
93	Fly	mouche	memory	3.02	1.06	4.10	0.92
98	Fox	renard	memory	1.95	0.84	4.02	0.85
100	Frog	grenouille	memory	2.48	1.05	3.42	1.05
102	Garbage can	poubelle	lure	4.08	1.10	2.58	0.74
103	Giraffe	girafe	lure	1.80	0.95	4.65	0.73
105	Glasses	lunette	memory	4.00	1.30	2.85	0.85
106	Glove	gant	memory	3.38	1.06	3.02	0.76
107	Goat	chèvre	lure	1.92	1.06	3.18	0.77
109	Grapes	raisin	lure	3.68	1.04	3.00	0.92
111	Guitar	guitare	memory	3.58	1.09	4.00	0.92
114	Hammer	marteau	memory	3.48	1.16	2.60	0.70
116	Hanger	ceintre	lure	4.52	0.67	1.20	0.56
117	Harp	harpe	memory	1.88	1.08	4.05	0.81
118	Hat	chapeau	memory	3.18	1.00	2.35	0.79
119	Heart	cœur	memory	3.72	1.16	1.00	0.00
121	Horse	cheval	lure	3.55	1.14	3.82	0.70
122	House	maison	lure	4.38	1.04	3.90	0.94
124	Ironing booard	planche	memory	3.50	1.07	2.05	0.63
126	Kangaroo	kangourou	memory	1.92	1.15	3.98	0.88
128	Key	clé	memory	4.85	0.42	1.92	0.76
130	Knife	couteau	lure	4.45	0.84	1.92	0.68
131	Ladder	échelle	memory	3.35	1.15	2.32	0.61
132	Lamp	lampe	memory	4.20	0.95	1.85	0.61
133	Leaf	feuille	memory	4.30	0.75	2.52	0.77
135	Lemon	citron	lure	3.25	1.22	1.85	0.69
137	Lettuce	salade	lure	3.42	1.24	3.48	0.92
143	Lock	cadena	memory	3.18	1.18	2.22	0.69
145	Monkey	singe	memory	2.58	0.97	3.90	0.70
146	Moon	lune	memory	3.98	1.10	1.02	0.16
147	Motorcycle	moto	memory	3.25	1.09	4.78	0.47
148	Mountain	montagne	lure	2.70	1.19	2.80	1.05
149	Mouse	souris	lure	2.45	1.02	3.28	0.87
150	Mushroom	champignon	memory	2.88	1.23	3.12	0.71
151	Nail	clou	lure	3.28	1.20	1.80	0.68
153	Necklace	collier	lure	2.70	1.31	1.78	0.88
155	Nose	nez	memory	4.52	0.87	1.60	0.92
157	onion	oignon	lure	3.32	1.31	2.85	0.96
160	Owl	hibou	lure	2.22	1.06	4.22	0.72
161	Paintbrush	pinceau	lure	2.78	1.24	2.58	0.95
162	Pants	pantalon	lure	4.55	0.86	2.22	0.70
164	Peacock	paon	memory	2.05	1.05	4.75	0.43
167	Pen	stylo	lure	4.78	0.72	3.15	0.94
168	Pencil	crayon	lure	4.42	1.00	2.32	0.91
169	Penguin	pingouin	lure	1.70	0.93	2.82	0.70
170	Pepper	poivron	lure	2.92	1.29	2.48	0.95
171	Piano	piano	memory	3.42	1.48	4.58	0.77

(*continued on next page*)

(*continued*)

172	Pig	cochon	memory	2.18	0.97	3.00	0.81
173	Pineapple	ananas	memory	2.95	1.30	4.35	1.01
174	Pipe	pipe	memory	2.90	1.14	1.88	0.71
176	Pliers	pince	lure	3.38	1.13	2.20	0.60
177	Plug	prise	lure	4.18	0.77	2.25	0.70
178	Pocketbook	sac	memory	3.95	1.28	2.70	0.78
180	Potato	patate	memory	3.46	1.17	2.20	1.10
181	Pumpkin	citrouille	memory	3.08	1.35	2.60	0.70
182	Rabbit	lapin	memory	2.95	1.07	3.28	0.84
187	Ring	bague	memory	3.48	1.28	2.55	0.80
189	Roller skate	patin	memory	2.25	1.11	4.08	0.93
190	Roller pin	rouleau	lure	2.22	1.08	1.52	0.50
192	Ruller	règle	memory	3.58	0.95	1.85	0.94
193	Sailboat	bateau	lure	2.92	1.17	3.58	0.92
194	Saltshaker	sel	memory	4.18	0.92	3.00	0.92
195	Sandwich	sandwich	lure	4.45	0.97	3.42	0.86
196	Saw	scie	lure	2.92	1.19	2.25	0.62
197	Scissors	ciseau	lure	3.98	0.99	2.15	0.65
199	Screwdriver	tournevis	lure	3.42	1.14	2.35	0.73
201	Seal	phoque	lure	1.62	0.73	2.90	0.74
202	Sheep	mouton	memory	1.85	0.82	3.80	0.75
203	Shirt	chemise	lure	4.56	0.70	3.08	0.79
204	Shoe	chaussure	memory	4.62	0.70	3.38	0.86
205	Skirt	jupe	memory	3.64	1.53	1.40	0.58
207	Sled	luge	lure	2.80	1.03	3.05	0.84
208	Snail	escargot	memory	1.85	1.06	3.40	0.80
209	Snake	serpent	lure	1.90	1.04	4.52	0.81
212	Spider	araignée	memory	2.28	1.10	3.68	0.85
214	Spool of thread	fil	memory	3.12	1.14	3.18	0.97
216	Squirrel	écureuil	lure	3.82	0.89	3.75	0.97
217	Star	étoile	lure	3.35	1.33	1.05	0.22
218	Stool	tabouret	memory	3.08	1.13	2.32	0.72
219	Stove	cuisine	memory	4.65	0.65	4.02	0.94
221	Suitcase	valise	lure	3.65	0.91	3.60	0.86
222	Sun	soleil	lure	4.90	0.30	1.20	0.46
223	Swan	cygne	lure	1.97	0.83	3.05	0.80
224	Sweater	pull	memory	4.48	0.74	2.90	0.77
226	Table	table	lure	4.35	0.88	1.72	0.77
229	Tennis racket	raquette	memory	3.62	1.30	3.25	0.94
233	Tiger	tigre	memory	2.10	0.92	4.62	0.80
236	Tomate	tomate	lure	3.78	1.06	1.98	0.57
238	Top	toupie	lure	1.88	0.98	2.65	0.82
239	Traffic light	feu	memory	4.55	0.80	3.45	0.84
240	Train	train	lure	4.15	0.88	4.32	0.88
241	Tree	arbre	lure	4.68	0.61	3.70	0.81
242	Truck	camion	lure	4.02	0.91	2.75	0.86
243	Trumpet	trompette	memory	2.60	1.26	3.58	0.92
244	Turtle	tortue	lure	2.40	1.14	3.62	0.89
245	Umbrella	parapluie	lure	3.95	0.92	3.00	1.05
246	Vase	vase	lure	2.78	1.26	3.15	0.66
247	Vest	gilet	lure	3.48	1.05	2.60	0.74
248	Violin	violon	lure	2.68	1.21	4.10	0.86
250	Watch	montre	memory	4.58	0.73	3.40	1.04
251	Watering can	arrosoir	lure	2.72	1.50	2.78	0.79
252	Watermelon	pastèqueue	memory	3.05	1.09	2.28	0.92
253	Well	puits	memory	1.45	0.70	3.82	0.74
254	Wheel	roue	lure	2.22	1.04	2.42	0.83
256	Windmill	moulin	lure	1.80	1.00	4.62	0.76
257	Window	fenêtre	lure	4.40	0.86	3.18	0.86
258	Wineglass	verre	memory	4.02	1.11	1.85	0.48
260	Zebra	zebre	memory	1.60	0.83	4.55	0.70

CRediT authorship contribution statement

Camos valerie: Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Belletier Clément:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Formal analysis, Conceptualization. **Wohlhauser Marion:** Data curation. **öncü Yagmur:** Data curation. **Mariz Elsig Stéphanie:** Data curation.

Data availability

Data will be made available on request.

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