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Latent Inhibition in Young Children: A Developmental Effect?

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Abstract

Previous research by Kaniel & Lubow in 1986 found that young children (aged 4-5 years) exhibited poorer learning (latent inhibition) to pre-exposed stimuli than older children (aged 7-10 years). The aim of our research was to develop a computer-based, child-friendly study that would replicate and extend the work of Kaniel & Lubow in a way that ruled out other, attention-based explanations of their effect. One hundred and four children and 32 undergraduate students took part in our experiment. This consisted of a pre-exposure/study phase in which participants were asked to press computer keys in response to clipart pictures of animals and dinosaurs. Each animal or dinosaur picture was preceded by one of two "warning signals" which acted as the pre-exposed stimuli (to which no response was required). In the test phase that followed, the participants had to either press the spacebar or withhold their response to each pre-exposed stimulus and two novel stimuli. They learnt which response was correct by trial and error using the feedback provided. The accuracy and reaction time of the responses during the test phase were analysed and indicated that the youngest children showed significantly lower mean accuracy and longer mean response times to the pre-exposed stimuli than to stimuli they had not been pre-exposed to. In contrast, the older children showed no significant differences in their responses to pre-exposed and novel stimuli. These results are consistent with those found by Kaniel & Lubow and as such provide additional evidence for latent inhibition in young children. We discuss the implications for theories of perceptual learning in humans.

Key Words: Latent inhibition, Developmental, Pre-exposure, Learning

Introduction

Do humans exhibit latent inhibition in the same way as other animals? Latent inhibition (LI) occurs as a result of being exposed to a stimulus without a conventional outcome. For instance, in the laboratory, latent inhibition is observed when animals such as rats that have been pre-exposed to a tone (without any other consequence) are slower to learn that the tone will subsequently predict a reward (such as food), than rats that had not previously been exposed to the tone, (first reported by Lubow and Moore, 1959 in sheep and goats; for an example with rats see McLaren et al, 1994b). LI is, in fact, relatively easy to find in animals but it is, by comparison, difficult to find straightforward evidence for this effect in humans using procedures similar to those employed with animals. By this we mean simple pre-exposure, where the stimulus, whatever it is, is simply presented to the participant in the experiment with no other stimulus or outcome contingent on it. Presentation of a tone or a light in a Skinner box will work very well in the case of a rat, but just presenting an equivalent stimulus to a human participant does not seem to reliably result in latent inhibition.

In their review of human LI experiments, Byrom et al (2018) agree with Graham and McLaren (1998) in suggesting that none of the studies that they review provide sufficient evidence to conclude that pre-exposure to a stimulus is the sole reason for the retarded responding observed. Other factors, such as negative priming (see Tipper, 1985 and Graham and McLaren, 1998), learned irrelevance or relative novelty are quite likely to be responsible for their findings. In order to provide a true test of LI in humans, it is necessary to develop experiments that are able to rule out these potentially confounding factors. And it is important to pursue this issue because it would be of great interest if humans were the only mammal tested that did not show latent inhibition in this straightforward manner. Conversely, if evidence could be found in humans for latent inhibition as a consequence of simple pre-exposure, then it would greatly enhance the plausibility of theories of perceptual learning such as that due to McLaren, Kaye and Mackintosh (1989, henceforth MKM) that base much of their analysis on a mechanism for latent inhibition.

One of the main mechanisms in the MKM theory of representation development is known as the differential latent inhibition of common elements. Without going into irrelevant detail at this juncture, it makes the case for the representational elements that are shared by two stimuli suffering from a greater amount of latent inhibition as a consequence of pre-exposure than those elements that are unique to the two stimuli. This then leads to perceptual learning, as the unique elements are now those that are more easily associated to / learned about than the common elements (which are responsible for generalization between the stimuli). Clearly this account relies heavily on latent inhibition as the primary mechanism driving this process and leading to perceptual learning. Thus, MKM is also a theory of latent inhibition in humans and other animals, and the status of latent inhibition in humans is a key issue in deciding its plausibility. That is the issue addressed in this paper.

Early studies on the Stimulus Familiarization Effect (Cantor, 1969) suggest that simple pre-exposure to a light is enough to produce a slowing in later reaction times to that same light in young children, whereas Meyer and Joseph (1968) were unable to find this effect in adults. Both of these findings were later confirmed by Lubow, Alek and Arzy (1975) in a direct comparison of young children and adults. These results can be taken to imply that simple pre-exposure in young children might lead to some diminution of salience that adversely affects speed of response in a simple reaction time task, and that this might be a marker for a latent inhibition effect, but obviously the nature of the effect is rather different to that seen in our rat example. Lubow, Rifkin and Alek (1976) were also able to show an effect of pre-exposure in young children that could more readily be interpreted as latent inhibition. In this case they pre-exposed cut-out shapes and were then able to show that learning of a later discrimination was slowed in some scenarios. The interpretation of these results is complicated by the fact that they also manipulated the familiarity of the context in which later testing took place and found that they only obtained a reduction in speed of learning when both stimulus and context had been pre-exposed, but a facilitation of learning when the stimulus had been pre-exposed and the context was novel. They were, however, able to replicate this result in rats, making a good case for there being a correspondence between the human and other animal results. Perhaps the best demonstration of LI in humans, however, is the later study by Kaniel & Lubow (1986). In their study, there was a relatively simple Exposure or Study Phase task in which children had to press buttons in response to pictures of plants and animals presented on metal cards in a box divided into three compartments. The cards were presented in sets of three, with one animal card and one plant card on each side of a third card (depicting two different sized black or white squares). During each trial the cards on either side of the middle card were changed and the child had to press a button corresponding to the side on which, for instance, the plant was present. In the following Test Phase, the children were presented with sets of cards showing black or white squares. This time they had to learn to press a button on the side corresponding to the card depicting the square that they had previously been exposed to in the study phase. They found that children aged 4-5 years exhibited reliably poorer learning compared to controls that had not been pre-exposed to the test stimuli, and that this effect disappeared in older children (7-10 year olds).

Can we take this as evidence of latent inhibition in young children? In one sense it can be argued that the procedure used in Kaniel and Lubow's experiment is an example of simple exposure to the square stimuli, as they are presented at central fixation. If we accept this, then this may indeed be an example of latent inhibition in young children that then disappears in somewhat older children. On the other hand, the requirement for the children to respond to the pictures of plants or animals could have acted as what Lubow and others have termed a “masking task” during the study phase, and so diverted their attention from the pre-exposed black or white square stimuli. If this is the case, then an explanation in terms of conditioned inattention to the stimuli (i.e. negative priming, see Graham and McLaren, 1998) would be preferred. One argument against the latter explanation, however, is that the effect is confined to just the youngest group of children. Given that masking task procedures can successfully produce retarded learning in adults (see Ginton, Urca and Lubow, 1975 for an early demonstration of this in the auditory modality as well as Graham and McLaren, 1998 for an example using visual stimuli), why would only the 5 year old children show the effect in this case? For this reason, Kaniel and Lubow’s results are some of the most interesting and potentially consequential for theories of associative learning as applied to humans that we are aware of.

There are, of course, some caveats with regard to these results. We have already mentioned the possibility of a conditioned inattention explanation of the data offered by Kaniel and Lubow (1986), and one reason why it may not have been considered an issue in that paper is that this is Lubow’s preferred explanation for latent inhibition in any case (see Lubow, 1989 for a whole book espousing this approach and a good deal of relevant material on this topic). Graham and McLaren argued in 1998 that this was not an appropriate explanation of latent inhibition in animals and used a perceptual learning paradigm to dissociate the effects of conditioned inattention (induced in adult humans using a masking procedure akin to Lubow's) from those of latent inhibition.

In Graham and McLaren's (1998) experiments, participants were incidentally exposed to two checkerboards (called "backs" in this study) in the context of classifying other checkerboards as members of one of two prototype-defined categories. They were able to show that this procedure was effective in slowing discrimination learning to these pre-exposed "backs", replicating the effect reported by Lubow and colleagues with quite different stimuli (e.g. Ginton, Urca and Lubow, 1975). To test whether this effect could be considered a demonstration of latent inhibition in humans, Graham and McLaren then ran a further experiment in which two new stimuli were produced by slightly distorting (changing a few squares) one of the "backs" after it had been pre-exposed, and then training a discrimination on these stimuli. The result was that acquisition of this discrimination was retarded compared to non-preexposed controls. Graham and McLaren argued that if the original retardation had been due to latent inhibition, then following work by Aitken, Bennet, McLaren and Mackintosh (1996), we should expect a discrimination between two distortions of one of these stimuli to be learnt significantly faster than controls as was the case for the pigeons in the Aitken et al study (see also Forgus, 1958a,b). This prediction also follows from the MKM theory, because the two distortions are produced by changing different squares in the original stimulus, and these mew features should not be affected by latent inhibition, and so be more salient than the other unchanged features in the stimuli. It is these new features that are required to solve the discrimination, and they will be at an advantage compared to the other features present and learning to them should proceed more rapidly. This is, in effect, the standard MKM argument for perceptual learning, and is exactly what Aitken et al (1996) found after exposing pigeons to one checkerboard, producing two distortions from that checkerboard, and then training the discrimination between them. The fact that Graham and McLaren did not obtain this result, but instead observed the opposite effect, can be taken to suggest that their pre-exposure effect is not latent inhibition but instead a form of negative priming (Tipper, 1985) that generalises to similar stimuli in such a way as to slow processing of the stimulus and retard learning.

This argument was further developed in McLaren, Wills and Graham (2011), where further evidence was provided for conditioned inattention as a consequence of masked pre-exposure in humans. In Kaniel and Lubow's experiment the task is, in effect, to classify the pictures of plants and animals whilst ignoring the geometric stimuli in between them. The analogy with Graham and McLaren's work is obvious, and it is possible to argue that the younger children had to learn to actively ignore these stimuli in order to accomplish the main task during pre-exposure, and this is why they were slower to learn about them later. There is little doubt, then, that we must take this possibility seriously and rule it out if we can, and we take the necessary steps to do that here. Another issue is that, as far as we are aware, Kaniel and Lubow’s (1986) results have not been replicated. While we have no reason to doubt them, and they do seem to form a coherent set with regard to the idea that young children will display a “raw” form of latent inhibition, replication would enhance our confidence that there is something real here. If they are to be taken at face value, then the implications for human learning are profound. We would need to ask why only children around 5 years of age show this effect, and in particular why it disappears by the age of 10? It is hard not to believe that such a finding would provide real clues about human development and the functioning of mature human learning and cognition. But before we can start theorising on these important issues, we need to be certain of our data.

Thus, our aim in this experiment was to design an updated and improved version of the Kaniel & Lubow study to see if we could replicate its findings, but without there potentially being a masking task involved. Our study uses clipart pictures of animals and dinosaurs for the children to respond to, one computer key for each. Instead of the pictures of different sized squares, we use two patterns taken from four possibilities as our pre-exposed stimuli. These two patterns are presented in the exposure or study phase as “warning signals” prior to an animal or dinosaur appearing, the other two serve as controls. In the test phase, all four patterns are presented, and the participants have to learn to either respond or withhold their response to each pattern. An effect of pre-exposure can be detected by comparing performance to the pre-exposed and control stimuli for each participant. This design brings with it a number of advantages over Kaniel and Lubow's original. Because the stimuli being pre-exposed are used as warning signals and are not present at the same time as the choice stimuli during the pre-exposure phase, participants do not have to ignore them to focus on the relevant stimuli. This should avoid any chance of conditioned inattention developing during pre-exposure. And, because we use both pre-exposed and non-pre-exposed stimuli in both conditions (respond and withhold response) in our test, we can see whether any learning deficit depends on whether people have to learn to respond to that stimulus or not. Finally, this is a within-subject rather than between-subject design, so replication would both confirm the robustness of this effect and provide a more efficient experimental paradigm for future investigation.

Our predictions are based on Kaniel and Lubow's earlier results. We expect to find reduced learning as a consequence of pre-exposure in the youngest children, with this effect steadily reducing with increasing age and eventually disappearing entirely (certainly for the undergraduates in this study). We also expect a standard developmental effect, with older participants performing generally better than younger ones.

Experiment

Method

Participants

104 primary school children (these were all that were available to us) and 32 undergraduate students took part in the experiment. The number of participants in each age group was as follows: 4-5 year olds (30), 6-9 year olds (40), 10-11 year olds (34), 18-22 year olds (32). The children were from four primary schools, two in Devon tested by one experimenter (RM) and two in Dorset tested by another (DH, trained by RM), and the three age groupings roughly correspond to those used by Kaniel and Lubow, allowing for

differences in the educational systems in the countries involved. Children in each age group were taken from the same classes at each school (e.g. 4-5 years old children taken from reception class), and all the schools were in similar socio-economic areas. The undergraduates were all from the University of Exeter and tested by a third experimenter (SB, also trained by RM). All the participants were selected using the safety screening criteria approved by the Research Ethics Committee at the University of Exeter. None of the children were specially selected or pre-trained on computer use, but we did exclude any children with special educational needs from the study, and any children that had been advanced a year educationally. This is because we expected our data to be developmentally sensitive, and so needed to standardise our samples at different ages as much as possible.

Materials and Design

Study phase. The experiment initially consisted of a pre-exposure or study phase of 120 trials (in random order) in which the participant had to respond to clipart pictures of dinosaurs and animals (examples in Fig. 1top), each preceded by a "warning signal" (one of the four possible stimuli shown in Fig. 1bottom). These stimuli were chosen to be obviously different from one another, and from the animal and dinosaur pictures. The idea behind this was to guard against the possibility of latent inhibition leading to perceptual learning for these stimuli[1]

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[1] It is well established that perceptual learning only occurs if the stimuli to be discriminated are sufficiently similar so that the discrimination is difficult, see, for example, Oswalt (1972), Chamizo and Mackintosh (1989), Trobalon, Sansa, Chamizo and Mackintosh (1991) and Mackintosh, Kaye and Bennett (1991). Rodrigo, Chamizo, McLaren and Mackintosh (1994) show that pre-exposure to otherwise easily discriminated stimuli can subsequently result in a retardation in acquisition of that discrimination.

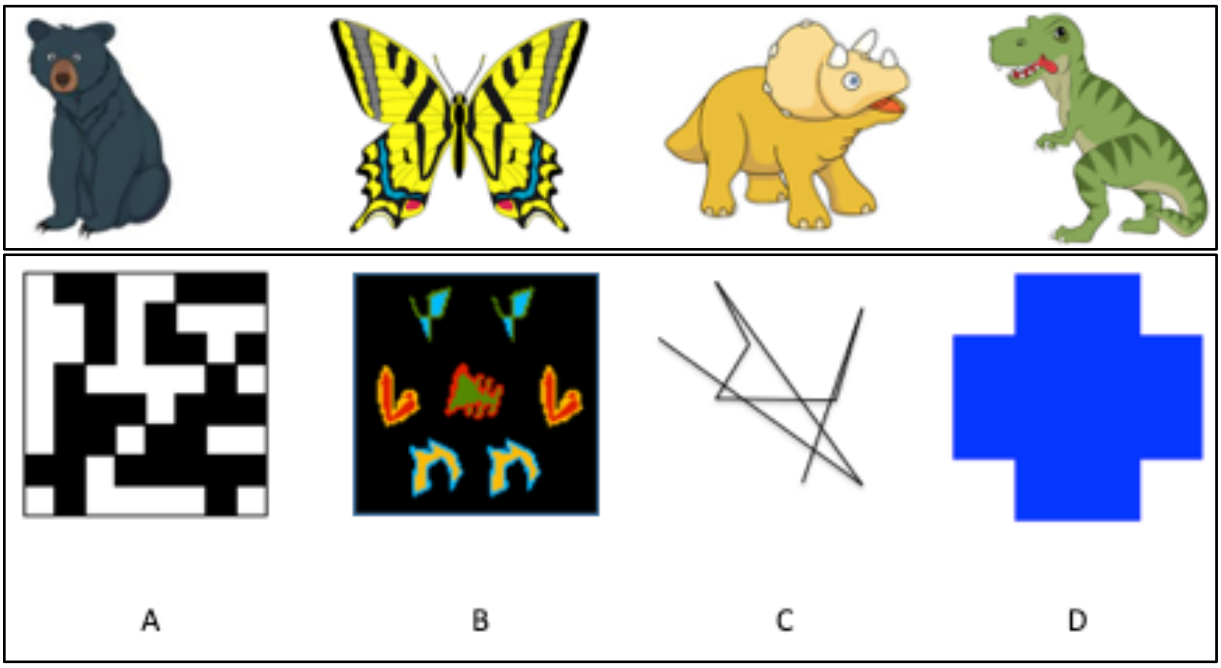

Figure 1. Top panel: Examples of clipart images (300 x 300 pixels) of animals and dinosaurs presented during the pre-exposure/study phase of the experiment. Bottom panel: "Warning signal" stimuli (128 x 128 pixels). Two of these stimuli appeared during the pre-exposure/study phase; all four appeared during the test phase.

During this phase, only two of the stimuli shown in Fig. 1 (bottom) were used to provide a warning that the next animal or dinosaur stimulus was about to be displayed (these were the pre-exposed stimuli). Each warning stimulus appeared equally often preceding each choice stimulus.

Test phase. The study phase was followed by a test phase of 64 trials in which the participant had to learn to either press the spacebar or withhold their response to each of four stimuli, two of which had been pre-exposed during the study phase. The two stimuli for which a spacebar response was required included one of the pre-exposed stimuli and one of the novel controls, and likewise for the stimuli for which the response had to be withheld. Stimuli were counterbalanced across conditions and subjects by creating four versions of the study (see Table 1). The experiment was developed using SuperLab 4 software (version 4.0.7b) and was presented on a Macintosh laptop computer.

Table 1. Counterbalance for stimuli pre-exposed during the study phase and responses required in the test phase of the experiment (+ = press spacebar, - = withhold response).

Counterbalance	Study phase stimuli	Test phase response
1	A and C	A+, B-, C-, D+
2	A and C	A-, B+, C+, D-
3	B and D	A+, B-, C-, D+
4	B and D	A-, B+, C+, D-

Procedure

Written consent was obtained from the parents/guardians of the children and from the students before they took part in the experiment. The consent form included information on the procedure of the experiment and the participants' right to withdraw at any time. The experimenter worked with one participant at a time in a quiet room at their school. At the start of the experiment the computer screen showed a picture of an imaginary island with a cartoon child "explorer". Overlaying the picture were written instructions. For each child participant, the experimenter read the onscreen instructions out loud, as follows:

> *Welcome to our study.*
> *Imagine you have just arrived on an island that has never been explored before.*
> *Your job is to look for animals.*
> *You soon find out that some animals look just like dinosaurs. Could this be possible?*
> *Have dinosaurs somehow managed to survive on this remote island?*
> *You need to quickly and accurately record every dinosaur and animal you see.*
> *Press the 'x' key if you see a dinosaur.*
> *Press the '.' key if you see an animal that isn't a dinosaur.*
> *The computer will say 'yiha' if you get it right or 'oops' if you get it wrong.*
> *Try to get as many correct responses as you can.*
> *Please press the 'B' key to see some more instructions.*

Once the child had done this, or in some cases the experimenter had shown them how to do this, they then saw the following screen which the experimenter again read:

> *Before you see them there will be a signal to warn you that the animal or dinosaur is coming!*
>
> *Remember:*
>
> *- as soon as you see a dinosaur, press the 'x' key.*
>
> *- as soon as you see an animal that isn't a dinosaur, press the '.' key.*
>
> *When you're ready, press the 'B' key*

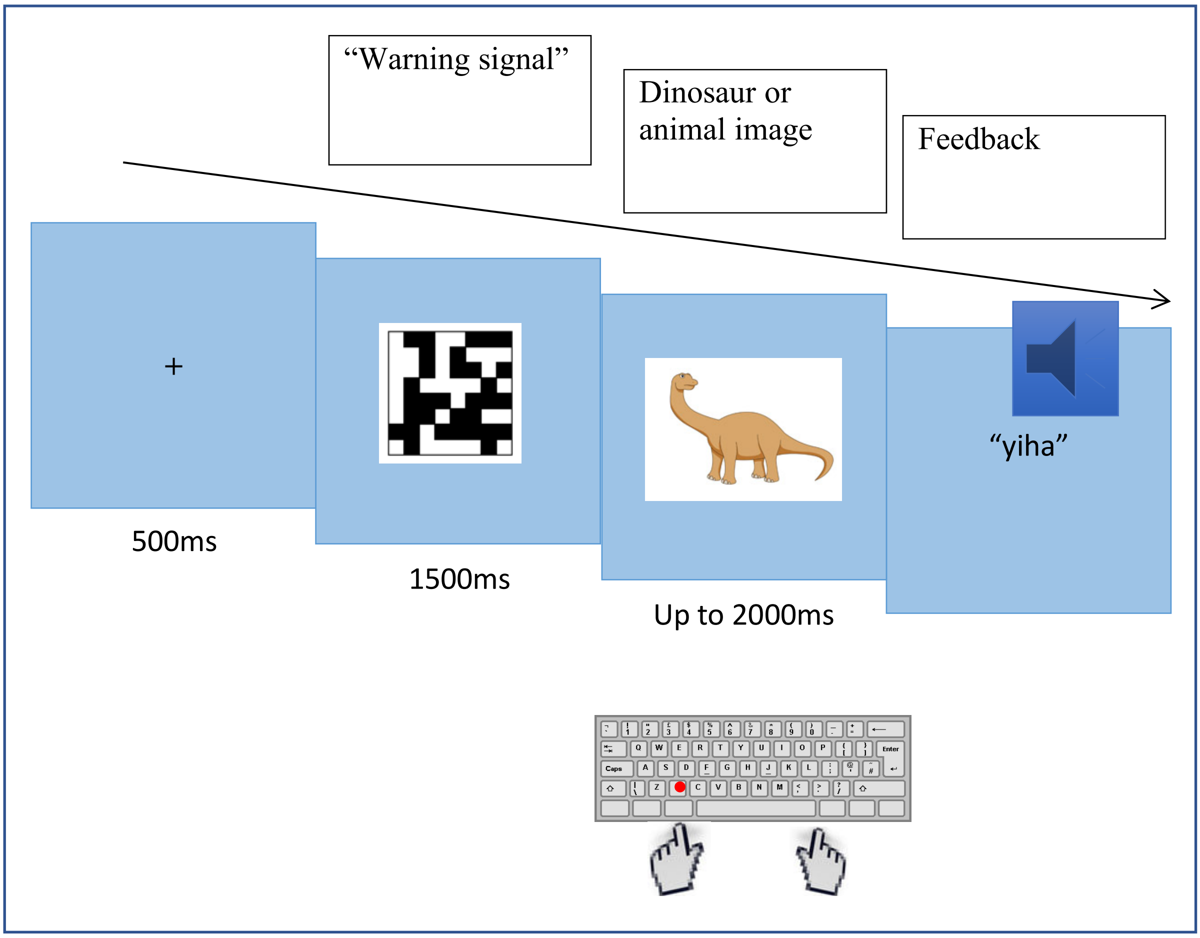

Figure 2. Example of a trial sequence during the pre-exposure/study phase.

Pre-exposure/study phase. There were 120 trials in two blocks of 60 with a participant break (self-timed) at the end of the first block. Each trial consisted of a fixation cross (500ms) followed by a warning signal (1500ms) followed by a dinosaur/animal image (up to 2000ms if no response). Feedback was given in the form of a "yiha" sound (correct response) or "oops" sound (incorrect response). If there was no response within the time-limit of 2000ms the feedback (presented on screen) was 'Oops – you took too long!'.

Figure 2 shows an example of a trial sequence during the pre-exposure/study phase. During this phase, each of the two warning signals (pre-exposed stimuli) was presented 60 times in random order (equally preceding the animal or dinosaur stimuli). Participants were not required to respond to the pre-exposed stimuli. At the end of this phase, the following instruction screen was presented. Again, the experimenter read these instructions out loud when working with children.

> *Thank you. You have recorded all the dinosaurs and animals on the island.*
> *Now the computer is going to show you some patterns.*
> *These patterns were used to label the island by people who used to live there a long time ago.*
> *Some parts of the island are safe to enter but others may be dangerous!*
> *You need to mark which parts are safe – you do this by pressing the "spacebar"*
> *And which ones aren't safe – for these don't press the "spacebar".*
> *You will just be guessing to start with. Try pressing and not pressing the "spacebar" when you see a pattern and see what happens.*
> *The computer will say "yiha" if you get it right or "oops" if you get it wrong.*
> *Please press the 'B' key to begin.*

Test phase. There were two blocks of 32 trials, with a participant break (self-paced) between them. Accuracy and reaction time were recorded for each trial during the test phase. During this phase, each trial consisted of a fixation cross (500 ms) followed by one of the four stimuli shown in bottom panel of Fig. 1 presented in a random order. These stimuli remained on screen up to the spacebar response or until 2000ms had elapsed if no response was made. If the spacebar was pressed, feedback ("yiha" or the "oops" sound) was provided immediately. If no response was made, feedback ("yiha" or "oops" sound) was provided after 2000ms. This enabled participants to learn, by trial and error, which type of response was required for each stimulus.

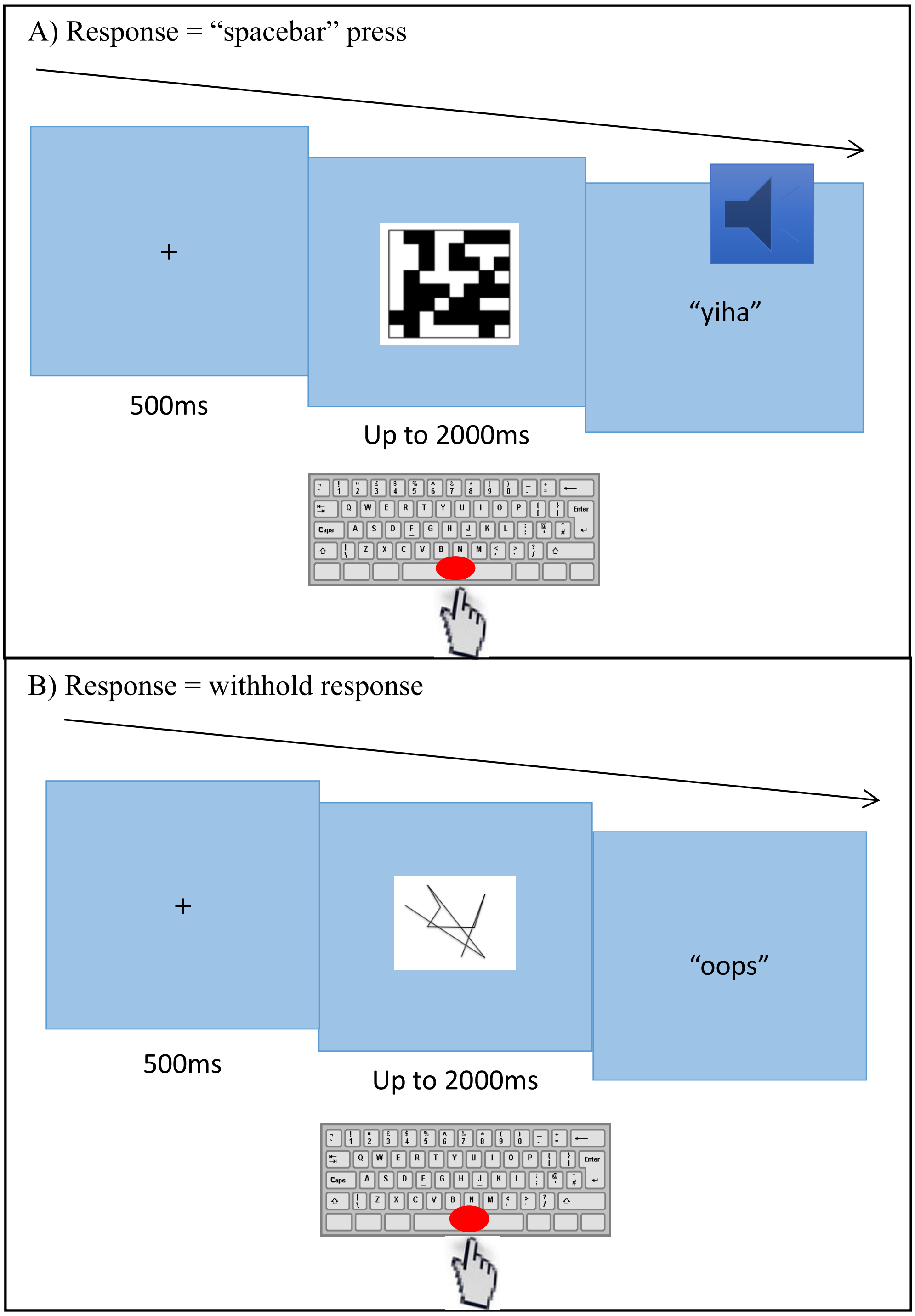

Figure 3. Examples of two Test phase trials in which the "spacebar" was pressed: Trial A required a response so feedback is "yiha". Trial B did not, but a spacebar press was made so feedback is "oops".

Figure 3 shows examples of two trials, one (Panel A), requiring the "spacebar" response, and the other (Panel B), requiring no response) during the test phase. Each stimulus (two pre-exposed during the study phase and two novel stimuli) appeared 8 times in a block. Two of the stimuli (one pre-exposed and one novel) required the “spacebar” response, the other two required the response to be withheld (i.e. no response).

Results

Data Analysis

The accuracy (our primary measure) and reaction time data collected during the test phase were first analysed using an overall mixed model ANOVA with a between factor of Age (Youngest, Middle, Oldest and Undergraduate) and within factors of Block (First vs. Second), Pre-exposure (Pre-exposed and Novel) and Response (Go and NoGo corresponding to a spacebar press or withheld response respectively), then followed up where appropriate with contrasts to establish whether there was a significant difference between responses to the stimuli that had been pre-exposed during the study phase compared to the novel stimuli, and whether this was dependent on the age of participants. Given the purpose of our study, we paid particular attention to analyses that allowed us to compare our results to those of Kaniel and Lubow (1986). A significance level of $p = .05$ was used for all statistical tests, which were two-tailed unless otherwise specified. We always intended to prioritise our analysis of the data from the first block of the test phase as, following an initial effort piloting this study, we realised that by the second block, most children had reached ceiling on the task, and as we shall see this was the case here. For completeness, however, we report the second block means, while focussing on the first block in subsequent analyses. We also report measures of variance and effect size where appropriate.

Preliminaries. We analyzed the pre-exposure data to check that there were no differences between the stimulus used as the S+ and the stimulus used as the S- in the subsequent test phase. There were none (Fs < 1 for all groups). There were, of course, considerable differences in performance on the classification task (dinosaur vs. other animal) in the different age groups. Mean accuracy was 72%, 94%, 96% and 98% going from Youngest children to Undergraduates.

Overall Accuracy. Our mixed model ANOVA on this measure showed that as expected, there was an overall effect of Block, F(1,132) = 260.6, *MSE* = 53419.04, p < .001, η^2_p = .66, capturing the improvement from Block 1 to Block 2 (see Figure 4). There was also a main effect of Pre-exposure, F(1,132) = 14.25, *MSE* = 1863.92, p < .001, η^2_p = .10, which reflected the general advantage for the novel stimuli over the pre-exposed stimuli. Our final within-subject main effect was for Response, F(1,132) = 13.44, *MSE* = 6444.28, p < .001, η^2_p = .09, as performance to the "Go" stimuli was typically higher than for "NoGo" (this can be seen by comparing the data shown in Figures 5 and 6). There was also the entirely expected main effect of Age, F(3,132) = 51.2, *MSE* = 708.82, p < .001, η^2_p = .54, indicating that older participants performed better than younger ones.

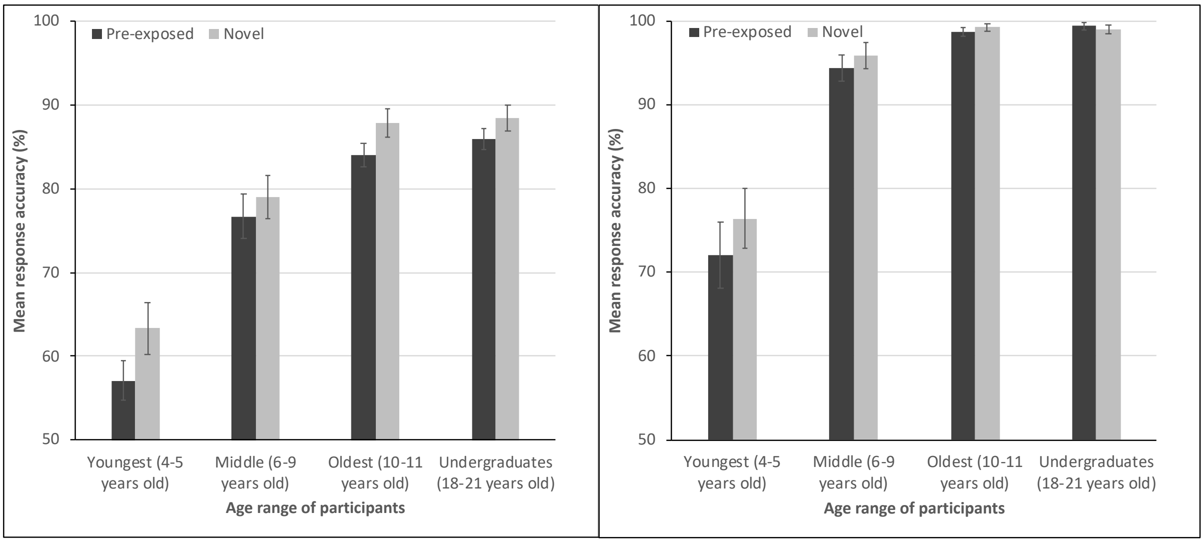

Figure 4. Mean percentage response accuracy (averaged over go and no-go stimuli) for the pre-exposed and novel stimuli for each age group during the test phase in Block 1 (left) and Block 2 (right). Error bars show SE of the mean.

Of more interest for present purposes are the interactions of the within factors with the between factor of Age. There are significant interactions between Block, Response and Age, F(3,132) = 3.07, *MSE* = 274.08, p = .03, η^2_p = .07, and between Block, Pre-exposure and Response, F(1,132) = 17.6, *MSE* = 2040.87, p < .001, η^2_p = .12. As we shall see when we look at Block 1 on its own, these interactions capture how the Response x Age and Pre-exposure x Response interactions in Block 1 change in Block 2 as a result of near asymptotic performance in three of the four groups of participants. The final significant interaction is perhaps the most important, as it speaks directly to the hypotheses under test in this study. This is the interaction between Pre-exposure, Response and Age, F(3,132) = 3.61, *MSE* = 144.95, p = .015, η^2_p = .08, which reflects the greater impact of pre-exposure on the youngest children, particularly on learning to the S+ (i.e. the "Go" stimulus). These effects can be seen in Figures 4 and 5. To further analyse them, and to ensure that our results were not simply an artefact of older participants reaching ceiling in Block 2 (which would naturally tend to reduce any effect of both pre-exposure and response requirements), we now pursue these effects in an analysis of the Block 1 data.

This established that there was still a significant three-way interaction between Age, Pre-exposure and Response in Block 1, F(3,132) = 3.33, *MSE* = 196.63, p = .022, η^2_p = .07, which motivated additional separate analyses of the Go and NoGo response data to fully interpret this effect. The main effects of Response, F(1,132) = 7.68, *MSE* = 3100.28, p = .006, η^2_p = .06, and Pre-exposure, F(1,132) = 10.05, *MSE* = 1889.09, p = .002, η^2_p = .07, that had been present in our overall analysis were still there. The interaction between the Response and Pre-exposure factors, F(1,132) = 29.74, *MSE* = 5847.93, p < .001, η^2_p = .18, such that accuracy to Go stimuli was lower if they had been pre-exposed than if they were novel, but accuracy to NoGo stimuli was higher if they had been pre-exposed was also present. We suspect that this interaction reflects a general tendency in all age groups to inhibit learning to respond to the pre-exposed stimuli, which would reduce accuracy when a go response was required but might facilitate withholding a response when that was appropriate. Note, however, that this result is qualified by the three-way interaction we have already mentioned between these factors and Age. One interpretation of this last interaction is that this tendency declines with age. The interactions between Age and Pre-exposure and Age and Response did not approach significance (Fs<1). As would be expected, mean response accuracy tended to increase with the participants' age. This was reflected in a highly significant main effect of the Age factor, $F(3,133) = 40.35$, $MSE = 474.03$, $p < .001$, $\eta^2_p = .48$.

Because of our predictions regarding the effects of pre-exposure on the youngest age group compared to other age groups, we ran some follow-up analyses focussed on this group. The 4-5 year-old children were the only age group to exhibit significantly lower overall accuracy of responding (averaged over Go = spacebar press and NoGo = withheld response) to the pre-exposed stimuli than to the novel stimuli, $F(1,29) = 4.89$, $MSE = 239.76$, $p = 0.035$, $\eta^2_p = .14$ (see Figure 4). This finding is consistent with a latent inhibition effect in the youngest children, and consistent with Kaniel and Lubow's (1986) findings. Whilst this effect is clearly numerically larger in the youngest children (also consistent with Kaniel and Lubow's findings) the difference between the youngest children and the other age groups is not itself significant. We return to this point later.

"Go" Trial Analysis. Figure 5 focuses on the response accuracy for "Go" stimuli i.e. those requiring a spacebar press (Pre-exposed + and Novel +) as a function of Age and Pre-exposure. We analysed the data using these two factors in a mixed model ANOVA following on from the significant three-way Age by Pre-exposure by Response interaction observed earlier. There was a significant main effect of Pre-exposure, $F(1,132) = 35.70$, $MSE = 7192.26$, $p < .001$, $\eta^2_p = .21$, with pre-exposed stimuli worse than novel stimuli. There was also a significant interaction between Age and Pre-exposure, $F(3,132) = 2.93$, $MSE = 201.45$, $p = .036$, $\eta^2_p = .06$, due to the effect of Pre-exposure being stronger in the youngest children than other age groups. There was the expected highly significant main effect of Age, $F(3,132) = 20.62$, $MSE = 494.27$, $p < .001$, $\eta^2_p = .32$.

We followed this analysis with some further tests designed to help us interpret this interaction. We first confirmed that the 4-5 year old, 6-9 year old and 10-11 year old children all show a significant difference in their response accuracy to "Go" stimuli as a function of pre-exposure, F(1,29) = 20.52, *MSE* = 535.80, p <0.001, η^2_p = .41, F(1,39) = 5.76, *MSE* = 552.40, p = 0.021, η^2_p = .13, and F(1,33) = 10.43, *MSE* = 247.86, p <0.005, η^2_p = .23, respectively.

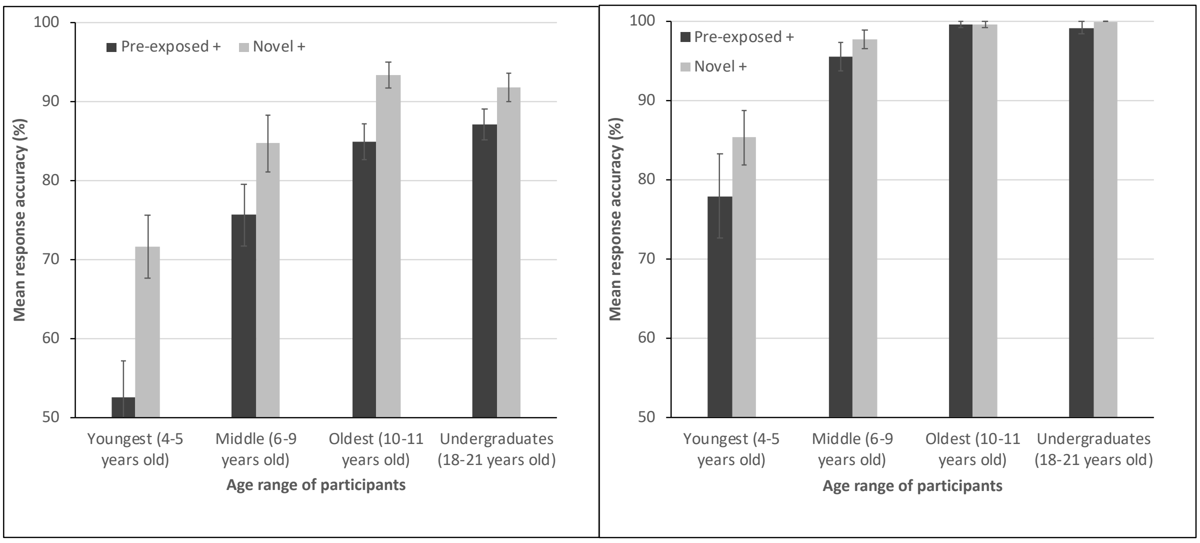

Figure 5. Mean percentage response accuracy for the pre-exposed and novel "Go" stimuli (requiring a spacebar press) for each age group during the test phase in Block 1 (left) and Block 2 (right). Error bars show SE of the mean.

Thus, there was a reliable reduction in accuracy to the pre-exposed stimuli for all age groups except undergraduates, F(1,31) = 3.06, *MSE* = 228.16, p = 0.089, η^2_p = .09, though the numerical trend was the same. In combination, this suggests there is an effect of pre-exposure on learning to the S+ across all ages.

We then looked at the differences between groups on this difference measure (i.e. the difference between performance on pre-exposed and novel "Go" stimuli). There is a significant difference when comparing the oldest to the youngest children, F(1,62) = 4.75, *MSE* = 1547.52, p =0.033, η^2_p = .07, and there is a trend towards significance for the comparison between the middle group and the youngest children, F(1,68) = 3.15, *MSE* = 2265.20, p = 0.08, η^2_p = .04. Unsurprisingly, the difference between the youngest children and adults on this measure is significant, F(1,60) = 8.58, *MSE* = 1511.56, p = .005, $\eta^2_p = .11$, but neither the difference between the 6-9 year old children and undergraduates nor the difference between the oldest children and the undergraduates is significant on this measure, max F(1,65) = 1.04, *p* = ns. It would seem, then, that the interaction is indeed due to the youngest children showing more of an effect of pre-exposure than the other groups on their learning to S+. Thus, the poorer learning exhibited by the youngest children is in part, at least, due to difficulty in learning to respond to the pre-exposed stimulus that requires a response. This fits well with Kaniel and Lubow's results which also showed that pre-exposure to the S+ was the effective procedure in retarding learning in their studies.

"NoGo" Trial Analysis. The stimuli that did not require any response produced a rather different pattern of results. Accuracy for the pre-exposed NoGo stimuli was somewhat higher than for the novel NoGo stimuli in the youngest children, a trend that declined in the middle and oldest children and reversed for the undergraduates (see Figure 6), but, as we shall see, the effect of Pre-exposure and the interaction between Pre-exposure and Age were not significant this time.

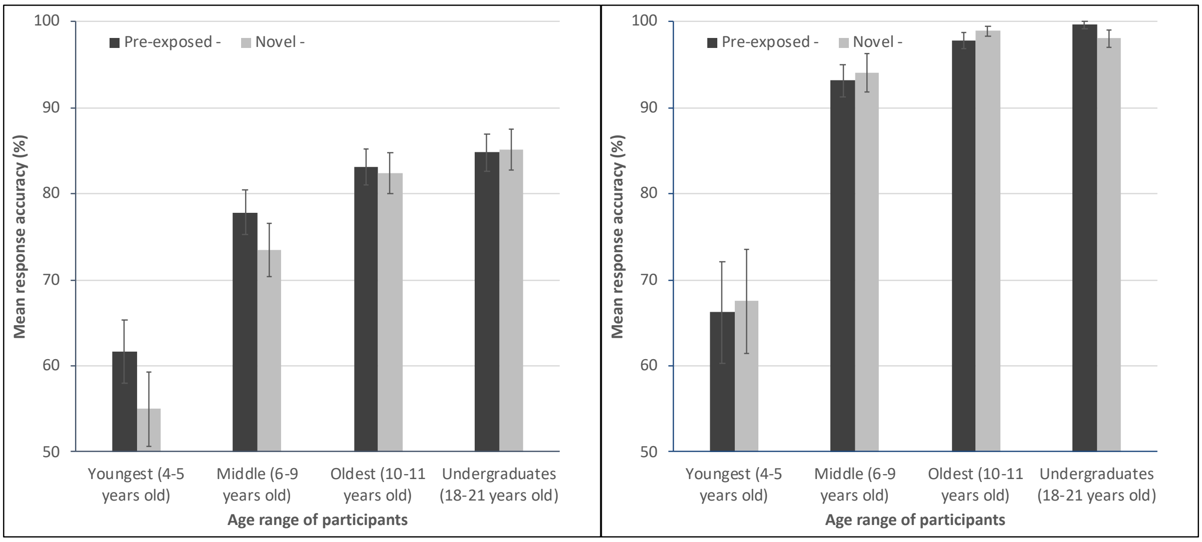

Figure 6. Mean percentage response accuracy for the pre-exposed and novel "No-Go" stimuli (requiring a withheld response) for each age group during the test phase in Block 1 (left) and Block 2 (right). Error bars show SE of the mean.

When we ran the same mixed model ANOVA on the NoGo data we did not obtain a significant effect of Pre-exposure, F(1,132) = 2.98, *MSE* = 544.76, p = .087, $\eta^2_p = .02$, there being only a trend for an enhancement in learning to not respond to the pre-exposed stimulus relative to the novel control. There was no reliable interaction between Age and Pre-exposure, F < 1, though there was the usual highly significant effect of Age, F(3,132) = 23.40, *MSE* = 383.58, p < .001, $\eta^2_p = .35$. Once again, these results to some extent parallel those of Kaniel and Lubow, who did not find a significant effect of pre-exposure to S- in their Experiment 2.

Latencies. This was not a speeded reaction time study, and so latencies to respond are not our primary measure and we do not report them in any detail here except to note that they do not in any way conflict with our results on the accuracy measure. As would be expected, the mean response times for the "Go" stimuli (averaged across pre-exposed and novel) were significantly longer for the youngest children when compared with the middle and oldest children. In addition, the mean response times for the older children were, in turn, significantly longer than those of the undergraduates.

The mean response times for pre-exposed "Go" stimuli were significantly longer than for the novel "Go" stimuli for the 6-9 year old children, F(1,39) = 4.88, *MSE* = 65578.40, p = 0.03, but this comparison was not significant for any of the other age groups (though numerically in the same direction). This difference did not itself differ significantly across any of the age groups, despite the extra time taken to pre-exposed stimuli being considerably greater numerically in the younger children than in the older two groups.

General Discussion

The aim of this study was to replicate Kaniel and Lubow's (1986) findings using a method that avoided any need to ignore the pre-exposed stimuli while performing the initial task. In this we succeeded. There is really quite strong evidence in our data for retarded learning as a consequence of pre-exposure in our youngest group of children, and this is the same age group that Kaniel and Lubow obtained their effect with. We have also failed to find a significant pre-exposure effect in terms of overall accuracy in older children, again mirroring Kaniel and Lubow's results. The pre-exposure effect has been predominantly on the S+ rather than the S- in the discrimination that has been used to test participants after pre-exposure as Kaniel and Lubow also report. Whilst this effect on "Go" trials has been present in the older children as well, it is significantly stronger in the youngest children. Given this, are we able to say that we have established that young children display latent inhibition as a consequence of simple pre-exposure to stimuli?

Before answering this question, the first issue that we have to address is whether the very different levels of performance on our test discriminations call any of our conclusions into doubt. A specific issue is whether the undergraduate group are at ceiling even in Block 1, and as such are bound to show a small difference between pre-exposed and novel stimuli simply because they are at asymptote in terms of task performance to both types of stimulus. In fact, one of our reasons for putting the undergraduate group in to this experiment was to establish what the ceiling level of performance on this task could realistically be taken to be. The task is designed for primary school children, so young adults should find it very easy indeed. And the evidence we have suggests that they did find it easy. They are just below 90% correct in the first block on this task, and when you consider that the first response to a stimulus must be a guess then this is nearly as good as it could feasibly be. Clearly, then, relying on comparisons between this group and the youngest children would not be valid. But that is not what we have done. The older primary school children are slightly worse, and the middle group of children are, in some sense, in the most sensitive part of the scale when it comes to detecting effects, as they are neither at ceiling or floor. Yet it is the youngest children, who may well suffer from a floor effect in the analysis of their go responses for pre-exposed stimuli, that show the greatest effect of pre-exposure. Given this, we think that the task difficulty was probably optimal for the primary school population tested, and that, if anything, the pre-exposure effect may be slightly underestimated in the youngest children.

To return to our original question, the answer has, for the present, to be yes and no. We begin with the positive case for latent inhibition: As we have already argued, there is now no particular reason to learn to ignore the pre-exposed stimuli during the initial phase of our experiment, because they actually serve a useful function, warning of the next stimulus to which a decision has to be made. One could always claim that the 4-5 year old children do learn to ignore these stimuli nevertheless, but that would seem a rather ad-hoc explanation of our results. And we would still be left with the conundrum of explaining why older children do not learn to ignore the pre-exposed stimuli if younger children do.

But in adapting our design to control for possible artefacts in Kaniel and Lubow's study, we may have introduced new ones into our experiment. One plausible explanation for these results takes note of the fact that the larger effect on learning seems to be on the pre-exposed stimulus to which a response was required during the final, test phase. The young children were particularly bad at learning to press the spacebar in the case of the pre-exposed S+, and the other children also showed some impairment in learning. Perhaps encountering the stimuli during the initial pre-exposure phase, when responses were required to the animal/dinosaur pictures but not to the warning stimuli has somehow caused this effect?

We can imagine a possible mechanism for producing our effect based on this idea. In a context where responses have to be made (press one of two keys), but when the warning signal is shown no response is required, then we can posit that general response inhibition accrues to that stimulus. As a consequence, when a response is required to these pre-exposed stimuli, it is harder to perform, because the initial inhibition has to be overcome. This explanation can be distinguished from one based on latent inhibition by noting that learning of both an excitatory association and of an inhibitory association between CS and US is retarded for a CS that has undergone latent inhibition. But the response inhibition account just given would predict that learning to withhold a response to a CS would actually be facilitated. The question, then, is how learning to respond to the pre-exposed S- progressed in the test phase. The answer in our data is that there is no significant evidence of a facilitatory effect in our experiment, although there is a weak numerical trend in this direction. Given this, a response inhibition account that completely explains the poorer learning seen in the youngest children seems less likely. The fact that we have an effect in our youngest age group for overall performance is also indicative of an effect that is not based on response inhibition. To make this argument explicit, it implies that the retardation in learning consequent on pre-exposure to the S+ is significantly greater than any facilitation that may have occurred as a result of pre-exposure to the S- in this age group. And a direct comparison of these two effects gives a significant result in favour of this hypothesis only for the youngest age group, $p = .035$.

Perhaps the most important argument for this being a demonstration of latent inhibition in young children, however, is generated by considering the two experiments, Kaniel and Lubow’s and ours, in combination. A response inhibition explanation will not obviously apply to Kaniel and Lubow’s design, as a response is made while the pre-exposed stimuli are being displayed. A learned inattention or negative priming explanation cannot easily be applied to our results, because there is no reason to ignore the pre-exposed stimuli. But both experiments give very similar results, which suggests a common explanation for those results, and latent inhibition is a very plausible candidate for that purpose. Can we think of any other explanations that have the same degree of plausibility?

It may be that a combination of our critique of Kaniel and Lubow's original study, and our critique of our own results points the way forward here. If we for the moment assume that Kaniel and Lubow's results in young children were a product of learned inattention to the pre-exposed stimuli, then we might explain this as follows. Older children were able to follow instructions and simply not attend to the stimuli in the central region, whereas the younger children did not have this level of control and had to learn to not attend to those specific stimuli over a period of time. This then led to slower learning. In the case of our results, the younger children were unable to configure themselves to not respond to the warning stimuli and had to learn this over time, whereas the older children and adults were better able to implement these instructions and thus did not need to learn to inhibit responding to particular stimuli. In both cases the result in the youngest children could thus be ascribed to poorer cognitive control, and this is also a very plausible hypothesis. It does rely on two separate explanations for the slower learning seen in these experiments, and so the latent inhibition hypothesis can be considered more likely, but it is certainly not possible to rule this alternative explanation out as matters stand.

Given this analysis, we would agree that further work is needed to establish unequivocally that it is latent inhibition observed in our and Kaniel and Lubow's experiments. A replication of the current experiment run in parallel with another version of the experiment that simply adds the requirement for a spacebar press to move from the warning stimulus screen to the dinosaur / other animal classification screen during the study / pre-exposure phase would serve this purpose. The latter variant would remove any possibility of response inhibition accruing to the pre-exposed stimuli. Running both versions would allow us to assay the potential contribution of response inhibition to the effect, as well as dissociating this from any latent inhibition effect. If the same retardation in learning to S+ were to be found in both versions of the experiment, then the case for it being latent inhibition would become very strong indeed. If, instead, the effect swapped over to the S-, then a response inhibition account would be preferred.

We finish by considering the implications that would follow if we were to establish, beyond doubt, that young childen do display latent inhibition in a way that is strikingly similar to that observed in the rat and other animals. One obvious corollary of such a conclusion is that it would make our account of perceptual learning (which can be found in its earliest form in McLaren, Kaye and Mackintosh [MKM], 1989, and has been updated in McLaren and Mackintosh, 2000, and McLaren, Forrest and McLaren, 2012) much more plausible, as it relies on latent inhibition. We posit a reduction in the salience of the features of a stimulus as a consequence of pre-exposure due to those features becoming predicted by other features present. This reduction in salience (learning rate) for these pre-exposed features results in latent inhibition. We then use conditioned attention to explain why such simple pre-exposure does not lead to observable latent inhibition in older children and adults. We argue that people attend to stimuli that are placed in front of them (on a whole stimulus basis, not just feature by feature as is the case with our mechanism for latent inhibition), and that this attentional response then becomes linked to those stimuli, compensating for any effect of latent inhibition. This attentional response is absent in younger children, which is what produces our and Kaniel and Lubow's results.

Up until now this argument has been supported by evidence that is, at best, indirect. A good example of this can be found in the results for the "fronts" in Graham and McLaren (1998). Unlike the "backs" that were pre-exposed using a masking procedure, the fronts were simply pre-exposed as part of the requirement to classify them as members of an A or B category. Each chequerboard "front" was an exemplar of one of these categories, which were each defined by a prototype with exemplars created in the standard way by adding noise to these prototypes. Discrimination training post-pre-exposure employed two novel exemplars of the A category (i.e. two new distortions of that stimulus). Whilst the results on test were not independently significant, there was a numerical advantage for the stimuli derived from the pre-exposed category compared to controls, and if we take into account similar studies, i.e. those in McLaren et al. (1994a), McLaren (1997), Civile et al. (2014) and Civile et al. (2016), then the evidence for this effect is overwhelming. The advantage for stimuli drawn from a pre-exposed category (that have not themselves been pre-exposed) is explained by their prototypical features being subject to latent inhibition, leaving their changed (and hence distinctive) features relatively salient which aids learning of a discrimination between them.

This is exactly the type of effect we can predict for the stimuli in our final proposed experiment. If we use our current pre-exposure procedure, but then take one of the pre-exposed stimuli, make two distortions of it, and train a discrimination between them, then that discrimination should be acquired faster than one involving novel control stimuli. Clearly there are differences between this design and the studies just considered, in that pre-exposure will be to a single stimulus of a given type rather than to a set of exemplars, but the principle remains the same. We expect latent inhibition to affect the pre-exposed features, and to not affect the changed features when we distort that stimulus to produce our two new versions of it. This should lead to an advantage in learning the discrimination between these two stimuli compared to suitable controls. The analysis is straightforward for the youngest children, and parallels that in Aitken et al. (1996) for pigeons and Forgus (1958a, b) for rats. But it is important to stress that this prediction also applies to the other age groups, including adults, as well. As long as we assume that an attentional process acts at a whole stimulus / object level to counteract the latent inhibition to features that should accrue as a consequence of pre-exposure, then we can predict that there will be a difference in relative salience between changed features and prototypical features (which will tend to be those shared by the stimuli). This difference in salience will then translate into enhanced learning of the discrimination involving the pre-exposed stimuli, as observed in the studies already reviewed, and as we predict will be the case for this design. Such a study would provide valuable convergent evidence for the latent inhibition hypothesis at all ages.

Conclusions

In conclusion, this study has provided further evidence for a retardation in learning to a stimulus following pre-exposure to that stimulus in young (4-5 year old) children. This effect was not found in older children. It is possible that what we have here is latent inhibition of the type obtained with simple pre-exposure in animals such as the rat, but more work will be needed to establish whether this is, in fact, the case. Possible alternative explanations are conditioned inattention / negative priming for Kaniel and Lubow's (1986) study, and generalised response inhibition for ours, but neither receive a great deal of support from the data we have obtained. Further research should focus on either definitively ruling these alternatives out or providing solid evidence for them.

If we have demonstrated latent inhibition in young children, then this has important implications for theories of learning, particularly of perceptual learning in humans. It would confirm that we carry with us the same basic processes affecting learning as other animals and would also go some way to confirming the MKM model of perceptual learning. More than that, it would also raise the question of why latent inhibition "goes away" in older children. We have given a possible reason here, which offers us one perspective on the development of learning and cognition in children. If it turns out not to be the case, and our results can be explained by some other mechanism, then this basic question will still remain. Why do young (4-5 years old) children show this effect and older children do not? Solving this developmental puzzle will add to our understanding of human mental life.

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