Pre-exposure and learning in young children: Evidence of latent inhibition?

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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 the work of Kaniel & Lubow. Sixty-three children 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 could be taken as evidence for latent inhibition in young children. Further studies are proposed in which variations in pre-exposure procedure are used to rule out explanations based on response inhibition or negative priming.

Introduction

Learning from experience takes place when connections or associations are formed between stimuli and outcomes, e.g. pricking a finger on a needle results in one learning that needles are sharp, so care is needed when handling them. Latent inhibition (LI) occurs as a result of being exposed to a stimulus without a noticeable outcome. For instance, in the laboratory, latent inhibition is observed when rats that have been pre-exposed to a tone are slower to learn that the tone will subsequently indicate a reward (such as food), than rats that had not previously been exposed to the tone, (Lubow and Moore, 1959; for an example with rats see McLaren et al, 1994). LI is relatively easy to find in animals but it is, by comparison, difficult to find evidence for this effect in humans.

In their review of human LI experiments, Byrom et al (2018), suggest that none of them 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 could also be responsible for their findings. In order to provide a true test of LI, it is necessary to develop human experiments that are able to rule out these potentially confounding factors.

One study that appears to provide evidence for LI in humans is that by Kaniel & Lubow (1986). In their study, there was a simple 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 poorer learning in this test than older children (7-10 year olds).

Can we take this as evidence of latent inhibition in young children? In one sense, 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. On the other hand, the requirement for the children to respond to the pictures of plants or animals could have acted as a masking task during the study phase and 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 these reasons, this Kaniel and Lubow's results are some of the most interesting and potentially consequential for theories of learning that we are aware of.

This study has, to our knowledge, never been successfully replicated. Our aim was to design an updated and improved version of the Kaniel & Lubow study to see if we could replicate its findings, but without there even being a hint of 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 four simple patterns as our pre-exposed stimuli. Two of the patterns are presented in the study phase as "warning signals" prior to an animal or dinosaur appearing. 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. 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 and focus on the relevant stimuli. 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.

Experiment

Method

Participants

Sixty-three primary school children took part in the experiment. The number of participants in each age group was as follows: 4-5 year olds (13), 6-9 year olds (40), 10-11 year olds (10). The children were all from a primary school a few miles outside Exeter, Devon.

Materials and Design

The experiment consisted of a **pre-exposure/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. 1), each preceded by a "warning signal" (Fig. 2).

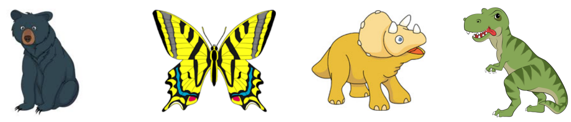


Figure 1. Examples of clipart images (300 x 300 pixels) of animals and dinosaurs presented during the pre-exposure/study phase of the experiment.

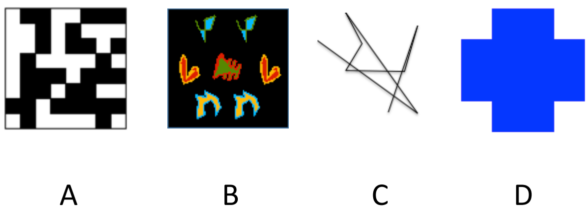


Figure 2. "Warning signal" stimuli (128 x 128 pixels). Two stimuli appeared during the pre-exposure/study phase; all four appeared during the test phase.

During the study phase, two of the stimuli shown in Fig. 2 were presented one at a time to provide a warning that the next animal or dinosaur stimulus was about to be displayed. Each warning stimulus appeared equally often preceding each choice stimulus.

The study phase was followed by a **test phase** of 32 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).

Table 1. Counterbalance for stimuli pre-exposed during the study phase and responses required in the test phase of each version 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-

The experiment was developed using SuperLab 4 software (version 4.0.7b) and was presented on a Macintosh laptop computer.

Procedure

Written consent was obtained from the parents/guardians of the children 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. 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 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.

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

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 "x" or "." response, or 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 3 shows an example of a trial sequence during the pre-exposure/study phase.

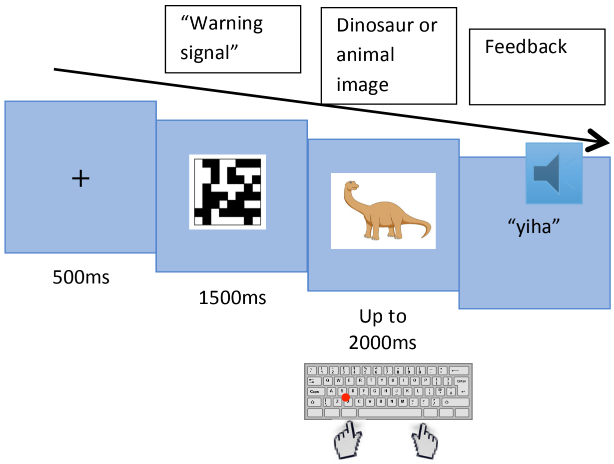


Figure 3. Example of a trial sequence during the pre-exposure/study phase.

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.

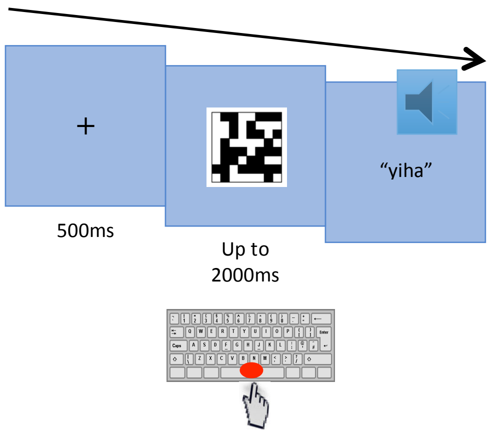
At the end of this phase, the following instruction screen was presented. Again, the experimenter read these instructions out loud when working with children.

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 32 trials in two blocks, with a participant break (self-paced) after the first 16 trials. 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 Fig. 2), 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 4 shows examples of two trials (one requiring the "spacebar" response, and the other requiring no response) during the test phase. Each stimulus (two pre-exposed during the study phase and two novel stimuli) appeared 8 times. Two of the stimuli (one pre-exposed and one novel) required the "spacebar" response. Two stimuli (one pre-exposed and one novel) required the response to be withheld (i.e. no response).

A) Response = "spacebar" press



B) Response = withhold response

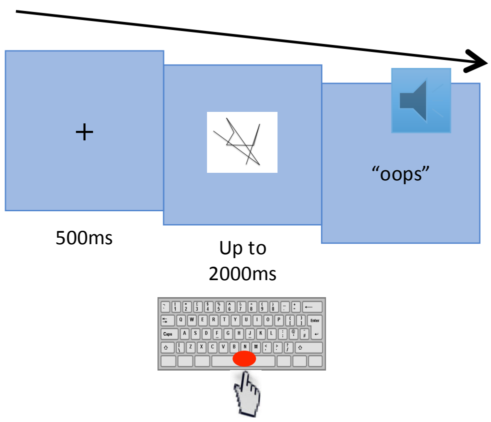


Figure 4. Examples of two Test phase trials in which the "spacebar" was pressed: Trial A required the "spacebar" response so feedback is "yiha". Trial B required the response to be withheld but a spacebar press was made so feedback is "oops".

Results

The accuracy and reaction time data collected during the first block of the test phase were analysed using t-tests 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. A significance level of p = .05 was used for all statistical tests, which were two-tailed unless otherwise specified. Only data from the first block of the test phase were analysed as, by the second block, most children had reached 100% accuracy.

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, t(12) = 3.57, p = .004 (see Figure 5). This finding is consistent with a latent inhibition effect in the youngest children, and consistent with Kaniel and Lubow's (1986) findings. The size of the effect was significantly greater than that observed in the oldest children, t(21) = 2.25, p = .035; and this difference also approached significance when the youngest and the middle age groups were compared, t(51) = 1.93, p = .059. This also replicates Kaniel and Lubow's (1986) findings.

As would be expected, mean response accuracy tended to increase with the children's age. The mean response accuracy of the oldest children (10-11 year olds) was significantly greater for both the pre-exposed t(21) = 4.51, p < 0.001, and novel t(21) = 3.18, p = 0.005, stimuli when compared with the youngest children. Only the difference for the pre-exposed stimuli is significant when comparing the middle group to the youngest, t(51) = 2.34, p = 0.023.

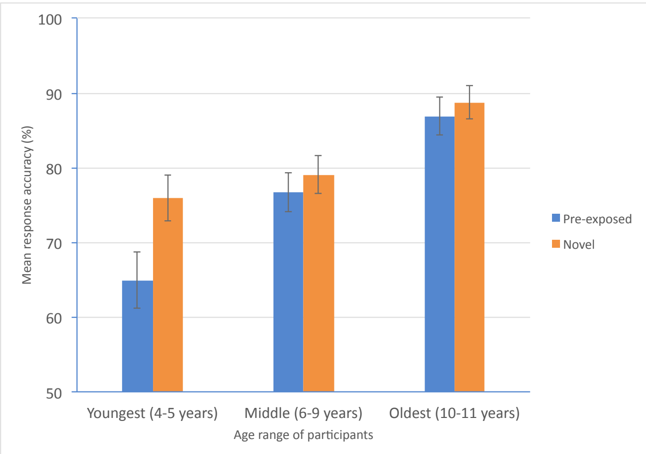


Figure 5. Mean percentage response accuracy (averaged over go and nogo stimuli) for the pre-exposed and novel stimuli for each age group during the test phase. Error bars show SE of the mean.

Figure 6 focuses on the response accuracy for those stimuli requiring a spacebar press (Pre-exposed + and Novel +). In this case, the 4-5 year old and 6-9 year old children both show a significant difference in their response accuracy (t(12) = 5.50, *p* <0.001 and t(39) = 2.40, *p* = 0.021 respectively) with a tendency to respond less accurately to the pre-exposed stimuli. In contrast, the older children show no reliable difference in their spacebar response accuracy to the pre-exposed and novel stimuli.

Once again we can look at the differences between groups on this measure. There isn't a significant difference when comparing the oldest to the youngest children (even though numerically the difference is large, this is probably a matter of power), but there is a trend towards significance for the comparison between the middle group and the youngest children, t(51) = 1.73, p = 0.09, a result that would be significant on a 1-tailed test. There is some evidence, then, that the poorer learning exhibited is in part, at least, due to difficulty in learning to respond to the pre-exposed stimulus that requires a response. There was no sign of such an effect for the pre-exposed stimulus that did not require a response.

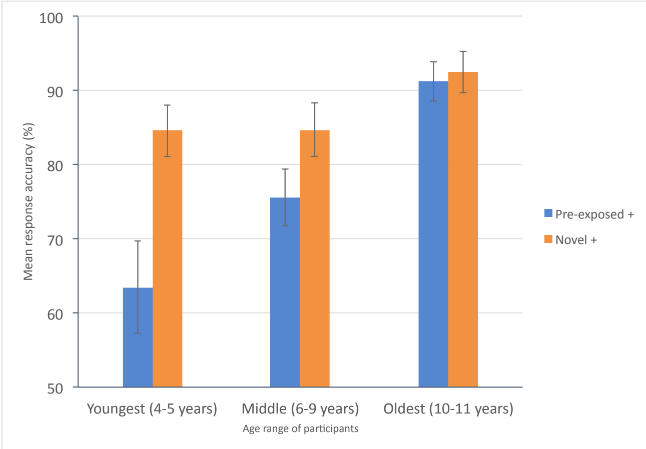


Figure 6. Mean percentage response accuracy for the stimuli requiring a spacebar press for each age group during the test phase. Error bars show SE of the mean.

The mean response times for stimuli requiring a spacebar press (Fig. 7) were significantly longer for the pre-exposed stimuli than the novel stimuli for both the 4-5 year old children (t(12) = 2.51, p = 0.027) and the 6-9 year old children (t(39) = 2.21, p = 0.033) but not in the oldest age group. But this difference did not itself differ significantly across groups, despite the extra time taken to pre-exposed stimuli being considerably greater numerically in the youngest children than in the other two groups. As would be expected, the youngest children generally exhibited longer response times for both types of stimulus than the oldest children.

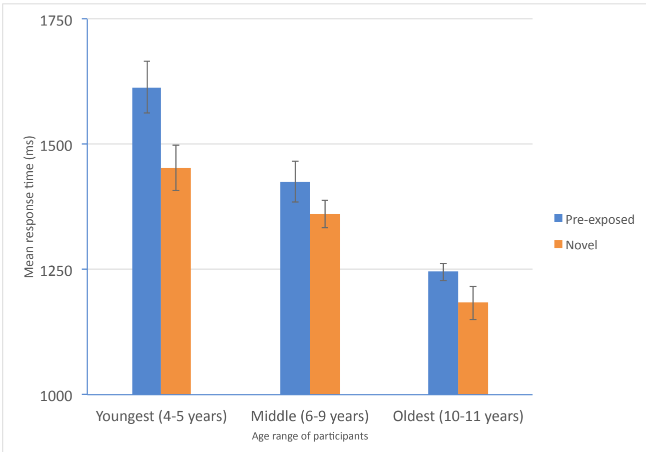


Figure 7. Mean response times (msec) for the pre-exposed and novel stimuli for each age group during the test phase. Error bars show SE of the mean.

General Discussion

The aim of this study was to replicate Kaniel and Lubow's (1986) findings using an updated method that avoided the 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 similar effect in older children, again mirroring Kaniel and Lubow's results, and all this with a pre-exposure procedure that uses the target stimuli as warning signals for an upcoming trial, so that there is no obvious need to ignore them. But can we be sure that this is latent inhibition in humans?

The answer to this question has, for the present, to be no. We cannot be sure that this is latent inhibition, but we can, perhaps, rule out some of the other possibilities. As we have argued, there is no particular reason to learn to ignore the pre-exposed stimuli during the initial phase of the experiment, because they actually serve a useful function, warning of the next stimulus to which a decision has to be made. One could always argue 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.

But in adapting our design to control for possible artifacts 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 middle age group also showed an impairment in learning. Perhaps encountering the stimuli during the initial pre-exposure phase when responses were required to the animal/dinosaur pictures and not having to make a response to the pre-exposed stimuli (because they were used as warning stimuli) has somehow caused this effect?

We can imagine at least two versions of this account. One would have it that being presented with the stimulus, followed by no outcome led to a type of CS->NoUS learning that has been suggested as producing the basic latent inhibition effect in other animals. Learning that this stimulus signals no outcome makes it harder to learn that an outcome does follow later. If this is the mechanism, then it would support the contention that the 4-5 year old children are displaying latent inhibition, as well as providing evidence for a particular theoretical explanation of latent inhibition.

A somewhat more concrete and specific version of this account would appeal to response inhibition developing rather than learning some general CS->NoUS association during pre-exposure. In a context where responses have to be made (press one of two keys), when the warning signal is shown no response is required and so general response inhibition accrues and is associated with the stimuli present at the time. As a consequence, when a response is required to these pre-exposed stimuli, it is harder to learn and perform. This explanation can be distinguished from our earlier one by noting that the result for latent inhibition is 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 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- progresses in the last, test phase. The answer in our data is that there is no evidence of a facilitatory effect in the youngest or oldest children, and there is only a hint of one in the middle group ($t(39) = 1.69$, $p = .099$. Given this, a response inhibition account of the poorer learning seen in the youngest children seems unlikely. 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.

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 on screen. 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 the only one that seems to fit is latent inhibition.

Which brings us to what may be the most intriguing feature of these results. The younger children, 4-5 years old, are the ones that show the effect. The older children either do not show any significant effect, or display a significantly weaker version of it. This is also something our study shares in common with Kaniel and Lubow's original work and needs some explanation. The explanation given in Lubow's 1989 book "Latent Inhibition and Conditioned Attention Theory" is that this "raw" latent inhibition found in young children is actually present in older children and adults, but that they have compensatory attentional processes that obscure this effect in studies of this type. In essence, latent inhibition reduces learning, but then attention is deployed to take it back up to its original level, hence no difference is observed between pre-exposed and non-pre-exposed conditions.

There is much to commend in this explanation, and one of us has offered something that at first sight is similar in McLaren, Wills and Graham (2010). But there are real differences, stemming from the fact that our account of latent inhibition (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) differs from that offered by Lubow. In Lubow's account, latent inhibition is due to conditioned inattention, but in ours it is due to a reduction in salience due to the features of the pre-exposed stimuli becoming predicted either by other stimuli present, or by one another. This leads to a reduction in salience (learning rate) for these pre-exposed features, hence latent inhibition. Instead, we use conditioned attention to explain why 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, 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 produces our and Kaniel and Lubow's results.

Why should we prefer this explanation to Lubow's? Both explanations are viable for the results obtained here and in Kaniel and Lubow's original study. But our explanation has the advantage of being able to explain Graham and McLaren's (1998) results as well as other demonstrations of retardations in learning in adults using a "masking" task (e.g. Ginton, Urca and Lubow, 1975). We argue that these results are indeed due to conditioned inattention, just as Lubow would have it, but disagree that this is the basis for latent inhibition. The test that Graham and McLaren use is to create two distortions of a pre-exposed stimulus and then train a discrimination between them. In their 1998 paper, they find that this results in slow learning of the discrimination when it is compared to a similar discrimination based on distortions of a novel stimulus. This is the opposite result to that found in animals (see Aitken, Bennet, McLaren and Mackintosh, 1996 for direct evidence on this point), and so suggests that the retardation in learning observed when the pre-exposed stimulus is trained directly is not actually latent inhibition but instead is due to negative priming. In future, we intend to apply this test to our finding. If we are able to demonstrate an enhancement of learning between two distorted versions of the pre-exposed stimulus (i.e. perceptual learning) using this technique then this will be excellent evidence that the effect is the same as that seen with simple pre-exposure in other animals, and confirm that it is latent inhibition and not negative priming.

Conclusions

In conclusion, this study has provided strong 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, and generalised response inhibition, 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 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 one 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 problem 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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