Age-Related Changes in Sensitivity to Relative Reward Frequency

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Older adults, younger adults, and children completed a signal-detection task which involved discriminating between two pattern types. Correct identifications of one pattern were reinforced three times more often than identification of the other. Performance was analyzed in terms of reaction time, accuracy (discriminability), and bias toward the more frequently reinforced alternative. The children had the fastest reaction times and the lowest discriminability scores. The younger adults were the most accurate at discriminating between the stimuli. The group of older adults had the slowest reaction times and showed the smallest response bias toward the more frequently reinforced alternative. Increasing task difficulty increased reaction times for the adult subjects, and reduced discriminability and response bias across all three groups. The results are consistent with an age-related reduction in sensitivity to the frequency of reinforcement.

It is generally accepted that the outcomes or consequences of a person's behaviour influence their future actions. Behaviour which is rewarded occurs more often, while punishment decreases the frequency of the behaviour it follows. Allowing for some developmental changes in sensitivity to different characteristics of outcomes (Mischel, 1984), these rules are assumed to apply across the lifespan. Evidence is accumulating, however, to suggest that older adults may be less influenced by the outcomes of their behaviour than younger generations.

In a critical review of the literature on probabilistic information processing and age, Sanford (1978) reported that the response patterns of older adults were less susceptible to reward manipulations than those of younger adults. For example, under conditions where participants were financially rewarded for correct guessing, younger adults showed the classical tendency toward maximization. Older adults failed to show such matching. Furthermore, increasing the magnitude of the rewards had no effect on the older participants' behaviour. Sanford (1978) concluded that the behaviour of older adults was characterized by "a reduced response to simple payoffs" (p 386).

Most of the research addressing age-related differences in response to reinforcement has focused on the extent to which reward promotes learning or skill acquisition; that is, cognitive or motor skill training. These studies have been of two types: comparisons of the performance of older adults under reinforced and nonreinforced conditions and, comparisons of the performance of younger and older adults on tasks incorporating external reward for performance. For the most part the results of these studies suggest external rewards do not enhance the performance of older adults (over and above the effects of practice), or that the effects are small.

Beach and Tennant (1992) compared the motor skill performance of older adults receiving either positive reinforcement or statements of personal importance with that of a control group. Reinforcement had no effect on the performance of older adults. Hill, Storandt, and Simeone (1990) assessed the effect of memory skills training and/or external reward on the free recall performance of older adults. Although both skills training and reward enhanced word recall, the effect was greater for skills training. Combining skills training with incentives was no more effective than skills training alone. As no younger adult comparision groups were included in these studies it is not clear if these results reflect the participants age, or some aspect of the tasks they completed.

In one of the few studies which directly compared the effects of reinforcement on skill acquisition in younger and older adults, Bellucci and Hoyer (1975) demonstrated that older adults were less influenced by rewards than their younger counterparts. Using a simple speeded performance task (digit symbol), they found younger women receiving noncontingent reinforcement improved more across trials than younger women in the control condition (no reinforcement) and also more than older women, irrespective of condition. Older women in the reinforcement condition completed only slightly more items than older women who received no feedback.

Although the results of these studies appear to support the hypothesis that older adults are less sensitive to the outcomes of their behaviour than younger generations, some caution is warranted. In most instances, the researchers have not considered the extent to which their older participants possess the skills required to perform the target behaviours. For example, in the studies cited above older participants' skill levels were not evaluated prior to reinforcement manipulation. If older adults are unable to complete the tasks required no amount of reinforcement will improve their performance. Alternatively, if participants are performing to capacity prior to the introduction of incentives then reinforcement is unlikely to improve their performance. Clearly a paradigm in which performance and response to feedback are not confounded is required to test the hypothesis that older adults are less influenced by the outcomes of their behaviour than younger generations.

Signal-detection procedures appear to offer a solution to this problem. Signal-detection performance, while sensitive to feedback, does not confound overall performance with response to feedback. Independent measures of skill level and sensitivity to reward are obtained. Furthermore, the signal-detection task can be designed to be performed comfortably by individuals across a wide range of ages.

In a signal-detection task, the participant is simply required to indicate which of two simuli (S_1 or S_2) has been presented by making an appropriate response (B_1 or B_2 respectively). Responses can be verbal (e.g., "yes" or "no") or mechanical (e.g., pushing one of two buttons). The experimenter can control the distribution of outcomes or "payoff" (e.g., feedback, points, or rewards) for correct responses with some precision. A number of experiments have shown that varying this distribution produces orderly changes in the participants' behaviour; that is, there is a systematic preference for the response producing the greater rate of payoff. This preference, often called the response bias, becomes larger as the asymmetry between the outcome frequencies on the two alternatives is increased (see Macmillan & Creelman, 1991 for a review).

There is already some evidence for age-related differences in response to feedback on a signal-detection task. McCarthy (1991) conducted a signal-detection analysis of continuous performance data collected from younger and older adult participants (McCarthy, 1977). Her reanalysis of the data showed that, compared with older adults, the younger adults had better discriminability on the task and their behaviour was more influenced by the distribution of outcomes obtained during the session. That is, the older adults showed less response bias. While interesting, this result must be treated cautiously. The original continuous performance task was not designed to investigate the effects of outcomes and the experimenters did not ensure each participant received a similar outcome distribution. In another study, Baron & Surdy (1990) exposed younger and older men to an extended continuous-recognition memory procedure in which they varied the payoff matrices for correct and incorrect recognitions. Signal-detection analyses of these data showed that while the older men demonstrated orderly transitions in the bias measure they showed a reduced sensitivity to changed contingencies relative to the younger men.

The present study used a signal-detection task to test the hypothesis that sensitivity to the effects of reward frequency decreases with age. Older adults (66-89 years), younger adults (18-26 years) and children (8-9 years) completed a signal-detection task which required them to make decisions about the relative number of circles and squares in a pattern presented on a computer screen. Two levels of task difficulty were incorporated because previous research in this laboratory has shown that if the discrimination task is too easy younger adult participants make few errors resulting in unstable response bias estimates. There is also some evidence from animal studies suggesting that high levels of discriminability may attenuate the effects of relative outcome frequency on performance (Alsop & Davison, 1991; Nevin, Cate, & Alsop, 1993). A group of children was included in the study to facilitate the assessment of differences in sensitivity to reward frequency across the lifespan.

If older adults are less sensitive to reinforcement than younger generations their performance in signal-detection procedures should differ from that of younger adults and children. Specifically there should be a difference in the extent to which asymmetric motivational-reinforcement factors produce bias in older adults. Based on the previous literature it is predicted that response bias toward the stimuli associated with more frequent reward will be smaller in older adults than in the younger adults and the children.

Method

Participants

Only data from participants with normal or corrected normal vision, sufficient manual dexterity to depress the keys on a two-key response panel, the absence of any illness or memory problems likely to impair signal-detection performance[1], and mean reaction times of at least 400 milliseconds and less than 10% very fast responses (i.e., reaction times of less than 100 milliseconds) were included in the study.

The participants included were 32 children (15 male and 17 female, 8-9 years, mean age = 8 years 9 months, *SD* = 6 months), 31 younger adults (13 male and 18 female, 18-26 years, mean age = 19 years 6 months, *SD* = 1 year 8 months), and 31 older adults (4 male and 27 female, 66-89 years, mean age = 76 years 11 months, *SD* = 7 years 1 month). The children were recruited from a local primary school, the younger adults from amongst first year psychology students at the University of Otago, and the older adults from three retirement villages (*n*=28) and a rest home

1 This exclusion criteria was applied to the older adult participants only.

(n=3). All of the participants were volunteers. In the case of the children, consent to participate was obtained from the child and their parents.

Apparatus

The experiment used a 486 IBM-compatible computer with a VGA colour monitor and TurboPascal™ software. Stimuli consisted of patterns of circles and squares arranged in a 12 X 12 array which appeared for three seconds (Johnstone & Alsop, 1996). There were two levels of task difficulty determined by the similarity in the number of circles and squares in the pattern. The "easy" stimuli contained 66 circles (or squares) and 78 squares (or circles). The ratio of the two shapes for the "difficult" stimuli was 70 to 74. Responses were made on a two-key response panel connected to the games port of the computer. The response panel consisted of two morse code keys set 200mm apart.

A brief health and mobility questionnaire was designed for completion by the older adults participating in the study. The questionnaire inquired about the participants: eyesight, mobility, level of independence, current health problems, and the presence and nature of any memory difficulties. Responses to this questionnaire were used to determine whether the older participant's data were appropriate for inclusion in the study.

Coloured plastic disks were used as token reinforcers. At the end of the signal detection task these could be exchanged for a small prize. The prize for children was a sheet of brightly coloured stickers, and for adults a $1.00 "scratch and win" lottery ticket. The lottery tickets were chosen for their physical similarity to the coloured stickers given to the children. Chocolate bars were available as a backup reward for any adult participants who did not wish to receive a lottery ticket.

Procedure

The children completed the experiment in a quiet room at their school, the younger adults were tested in the experimenters' research laboratory, and the older adults were tested in a quiet room at the facility where they lived.

Participants were seated approximately 400mm from the VGA monitor with the two-key response panel directly in front of them. The experiment began with a computer presentation of the instructions and a short demonstration of the procedure. The instructions were read aloud by the experimenter who determined the pace of their presentation, and provided clarification as necessary. The instructions (see Appendix 1) and the procedure used throughout were designed to be understood by the youngest group of participants. Adult participants were told this in advance.

Participants were told that a pattern of circles and squares would appear on the screen, and that they were to indicate if there were more circles or squares in the pattern by pushing the appropriate key on the response panel. They were told to press the left-hand key if there were more squares in the pattern and to press the right-hand key if there were more circles. Participants then received a practice trial with a pattern showing more squares than circles, and this was followed by a trial with a pattern showing more circles than squares. Once it was clear the participant understood the procedure the first experimental trial began. All experimental trials began with a cross flashed on the centre of the screen for 500 msec. This was followed by the presentation of a pattern of circles and squares on the screen. The pattern remained on the screen until the participant pressed one of the response keys or 3 seconds elapsed. If they did not respond within 3 seconds the screen went blank and remained that way until a response was made.

Not all correct responses were rewarded. The computer determined which correct responses were rewarded in a quasi-random order. For half the participants in each group, correct identification of patterns with more squares produced positive outcomes three times as often as correct identification of patterns with more circles. The remaining participants received the opposite distribution of outcomes. Rewards consisted of a colourful monitor display, including the words "Bonus 1000 points", sound effects, standardized verbal encouragement, and the subject earned a plastic token. Approximately 25 to 30 percent of correct responses were rewarded. Errors and non-rewarded correct responses had no programmed consequences. The screen remained blank for 1250 msec and the experimenter remained silent.

The experiment consisted of 360 trials in six blocks of 60 trials. There were three blocks of "easy" trials and three blocks of "hard" trials. Hard and easy blocks alternated. Within a block of trials the two pattern types were presented equally often in a quasi-random order. After every 60 trials, the experiment would pause and a message would appear on the screen reporting the number of points accumulated, congratulating the participant on their performance, and offering them a brief rest. At the end of the sixth block the message "End of test - Thank you. You have (number of points accumulated) points" appeared on the screen. The participant was then informed that he or she had acquired sufficient points to win a prize. The number of points required for a prize was never specified, and all participants, irrespective of performance, were offered a prize after completing the signal detection task.

Data collection

On each trial, the computer recorded which stimulus (pattern) was presented, which response was made, whether the response was rewarded, and the participant's reaction time.

The first 120 trials (one block of easy trials and one block of hard trials) served as a warm up period during which the participants became familiar with the stimuli and responses, and were exposed to the asymmetric (3:1 or 1:3) reward distributions. The data from the last four blocks of 60 trials were analysed.

Three measures of performance were calculated for each participant for each level of difficulty: the mean reaction time, the discriminability between the stimuli, and the response bias. Reaction time was measured as the time between stimulus onset and depression of the selected response key. Discriminability and response bias were assessed using measures from the behavioural model of signal-detection (e.g., Davison & Tustin, 1978; McCarthy & Davison, 1981). These measures are equivalent to those derived from Luce's (1963) choice theory, and they are directly comparable to those of Green and Swets' (1976) Signal-detection Theory. Discriminability between the sample stimuli was calculated by the equation,

$$\log d = \frac{1}{2}\log\left(\frac{Square_{corr}.Circle_{corr}}{Square_{incorr}.Circle_{incorr}}\right) \quad \text{Equation 1}$$

where $Square_{corr}$ denotes the number of correct responses following presentations of the pattern with more squares, $Circle_{incorr}$ denotes the number of incorrect responses following presentation of the pattern with more circles, and so forth. Response bias was calculated by,

$$\log b = \frac{1}{2}\log\left(\frac{Square_{corr}.Circle_{incorr}}{Square_{incorr}.Circle_{corr}}\right) \quad \text{Equation 2}$$

using the same notation as above.

Reaction time, discriminability, and response bias were compared across the three groups for the two levels of task difficulty. Some participants, in particular the children, produced reaction times which suggested that a response was triggered by stimulus onset rather than observing the stimuli (i.e., reaction times of less than 100 milliseconds). The results from these trials were not included in the analysis.

Results

Reaction Times

Figure 1 shows the mean reaction times for the two levels of task difficulty for each age group. Exploratory analysis indicated these data violated the assumption of homogeneity of variance required for the use of analysis of variance (ANOVA). As transformation of the data did not adequately address this problem reaction times were analysed with the non-parametric Kruskal Wallis (KW) one way analysis of variance by ranks procedure (between group comparisons) and paired t-tests (within group comparisons).

Median reaction times for the three groups were significantly different for both levels of task difficulty: easy $KW(2, 94) = 13.01, p = .0015$; hard $KW(2, 94) = 18.56, p = .0001$. Post hoc comparisons showed that the children responded more quickly (easy *Mdn* = 967.5, hard *Mdn* = 978.0) than the two adult groups, and that the younger adults (easy *Mdn* = 1049.0, hard *Mdn* = 1121.0) had faster reaction times than the participants in the older adult group (easy *Mdn* = 1275.0, hard *Mdn* = 1557.0).

The effect of increased task difficulty on reaction time was assessed with three paired t-tests. As suggested by Figure 1, increased task difficulty did not significantly increase the children's mean reaction time. For both adult groups, increased task difficulty was associated with a significant increase in mean reaction times: younger adults $t(30)=-3.32, p = .002$; older adults $t(30) = -3.69, p = .001$.

Discriminability

Figure 2 shows the mean discriminability scores for each level of task difficulty for each age group. The discriminability data were analysed with repeated measures analysis of variance with level of task difficulty as the repeated measure. There was a significant group by level of difficulty interaction $F(2, 91) = 11.13, p < .001$ (partial $h^2 = .19$, power = .99), indicating the decrease in discriminability associated with increased task difficulty was not uniform across groups. Parameter estimates showed

Figure 1. The mean reaction times (milliseconds) and their standard errors for the three age groups for easy and hard trials.

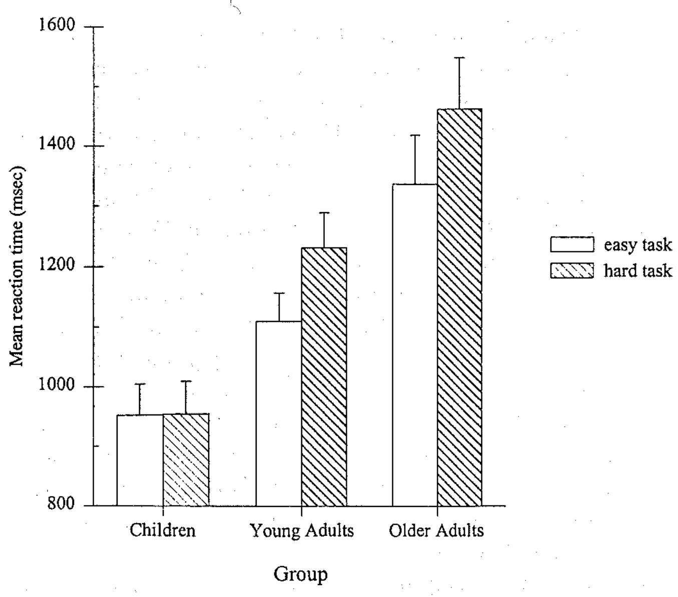
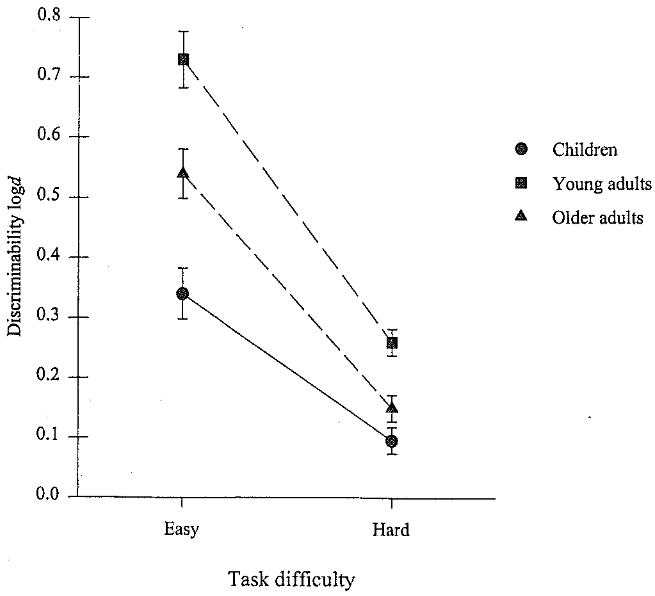


Figure 2. The mean discriminability scores (log d, Equation 1) and their standard errors for the three age groups for easy and hard trials.



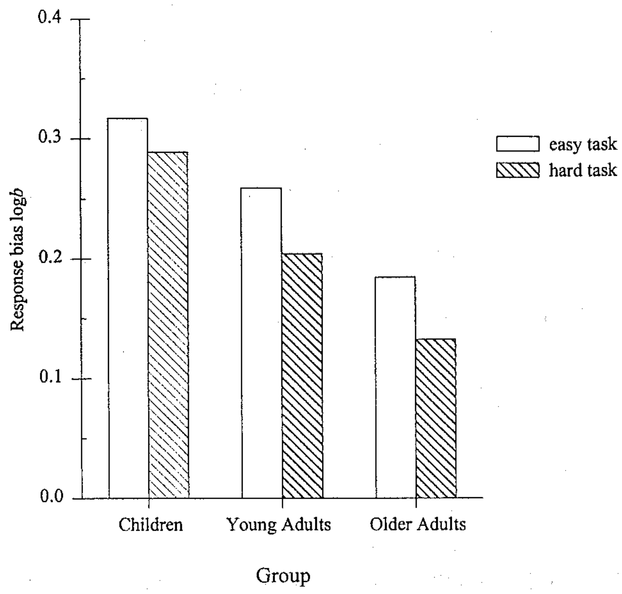
the decrease in discriminability in the older adult group was significantly greater than that observed for the children. The change in the level of discriminability between the two adult groups approached, but did not reach, significance. Significant main effects were observed for both group $F(2, 91) = 21.14, p < .001$ (partial $h^2 = .31$, power = 1.0) and level of task difficulty $F(1, 91) = 298.23, p < .001$ (partial $h^2 = .77$, power = 1.0). Parameter estimates indicated the children discriminated more poorly than the older adult group who in turn had lower discriminability scores than the younger adults. Discriminability scores for all three groups were lower for the hard trials.

Response Bias

Exploratory analysis of the bias scores indicated the presence of two individuals with extreme[2] bias scores on the easy trials (one child and one older adult) and one older adult with an extreme bias score on the hard trials. Data from these participants were excluded from further analysis of the bias scores. After checking the bias data met the necessary assumptions it was submitted to a repeated measures analysis of covariance (ANCOVA). Bias scores for the two levels of task difficulty were the repeated measure, while discriminability scores for the easy and hard trials were used as the variable covariate. Analysis of covariance was employed as bias and discriminability were found to correlate significantly for the easy trials $r = .39$, $p < .001$. Separate correlations for each group suggest this was largely due to the strong linear association between bias and discriminability in the younger adult group $r = .57, p = .001$.

Figure 3 shows the mean bias scores, adjusted for the covariate, for each level of task difficulty for each group. There was a significant main effect of group, $F(2, 87) = 5.99, p = .004$ (partial $h^2 = .12$, power = .87). Parameter estimates indicate the children showed a greater bias toward the more frequently reinforced alternative than the older adult group. The younger adult group had bias scores intermediate between the two other groups and these were not significantly different from either the children or the older adults. The main effect of level of task difficulty approached but did not reach significance, $F(1, 87) = 3.59$, $p = .062$ (partial $h^2 = .04$, power = .46). There was no evidence of a group by level of difficulty interaction.

Figure 3. The adjusted (co-varied) mean response bias scores (log b, Equation 2) for each age group for easy and hard trials. If the degree of bias matched the degree that the reinforcer frequncies were unqual, we would expect bias values of 0.60. As is common with humans and other animals, the bias undermatched the reinforcer distribution.



Discussion

The present study used signal-detection methodology to compare the sensitivity of older adults, younger adults, and children to the frequency of reward. The response bias data suggest that the sensitivity of behaviour to the relative frequency of reward declines progressively with age. In this study the older adult group showed a significantly smaller bias toward the more frequently reinforced alternative than the children. The mean response bias displayed by the younger adults was approximately midway between these two groups and was not significantly different from either group. A similar pattern of results was obtained for each level of task difficulty.

Analysis of the discriminability data suggests the ability to discriminate between the sample stimuli is developmentally linked. The younger adults showed the highest levels of discriminability, across hard and easy trials, followed by the older adults and then the children. Increased task difficulty reduced discriminability in all three groups, although the decline was not uniform. The older adult group showed a significantly greater decrease in discriminability with increased task difficulty than the children. As the children had the poorest discriminability to begin with, the limited change in this group may be due to a floor effect.

Reaction times were also developmentally linked in that mean reaction times increased with age. The children responded most quickly while the group of older adults had the slowest reaction times. The slowing of reaction times with age is widely recognised: "one of the most commonly observed changes with age is a decline in speed of performance" (Kline & Schieber, 1985, p 315), and was thus to be expected. However, as participants were not explicitly told to respond as quickly as possible reaction time differences may reflect differences in motivation as well as response speed. More interestingly, increased task difficulty slowed reaction times for the two adult groups but had no effect on the reaction times of the children. The most likely explanation for this is that the adult participants increased the time they spent in decision making as task difficulty increased. As the children's discriminability was low for both hard and easy trials they may have perceived no benefit in slowing their responses. Alternatively, their

2 Outlying values more than 3 box-lengths from the 25th or 75th percentile in a boxplot (50% of cases have values within the box).

low discriminability scores may simply reflect less time spent in decision making.

Consistent with previous research, the results of the present study suggest that the behaviour of the older adults may be less influenced by relative reward frequency than that of younger generations. Why is this? Given the mean age of the older adult group, it is possible that these individuals were unable to perform the task, and as a consequence received too few reinforcement opportunities to be influenced by the asymmetric reward distribution. This, however, does not appear to be the case. The older adult group's discriminability scores were actually better than those recorded by the children, who had the largest response bias. In addition, subject selection ensured that only older adults with sufficient manual dexterity to press the response keys, no evidence of memory difficulties, and normal, or corrected normal vision were included in the study. A limited skill hypothesis does not adequately explain the current findings.

An alternative explanation is that the older adults were less interested in the task and therefore did not pay as much attention to the consequences of their responses as the other groups. As interest level was not directly assessed this hypothesis cannot be completely ruled out by the data presented. However, our older adult participants were cooperative, eager to help, and tried to do well. All of the participants in this group completed all 360 signal-detection trials. Therefore, we do not believe that differences in motivation to participate were responsible for the smaller response bias observed for the older adults. Furthermore, it is important to note that the present study focuses on the relative distribution of rewards during the task and the influence that this distribution has on performance, rather than the absolute value of the rewards in their own right.

The ratio of male to female participants is similar for the child and younger adult groups. In the older adult group, however, many more women than men participated. This gender difference is an accurate reflection of the rest home and retirement village populations. While it is possible that the different gender distribution in the older adult group is linked to the reduced reward sensitivity of this group this does not seem very likely. We are not aware of any research suggesting that behaviour of human females is less sensitive to the effects of reward frequency than males. In addition, the younger adult group, with its more even distribution of male and female participants, also demonstrated reduced reward sensitivity relative to the children.

A more likely explanation for the current findings is that the reduced reward sensitivity is a direct consequence of the aging process, as suggested by McCarthy (1991). The question then becomes what aspect of the aging process would explain this decrease in sensitivity to reward frequency? One possibility involves age-related changes in dopaminergic function. The neurotransmitter dopamine is thought to play a critical role in incentive learning and hence it is implicated in the effects of reinforcement on behaviour (see Beninger, 1983; 1993 for reviews). Furthermore, post mortem and *in vivo* studies show striatal dopaminergic function decreases with age (De Keyser, Ebinger & Vauguelin, 1990; Fearnley & Lees, 1991; Martin, Palmer, Patlak, & Calne, 1989; Rieder & Wuketich, 1976; Scherman, Desnos, Darchen, Pollak, Javoy-Agid & Agid, 1989; Severson, Marcusson, Winbald & Finch, 1982; Wong et al., 1984). Therefore, the decreased sensitivity of the older adults to reinforcer frequency might be a direct (or indirect) result of the reduced dopaminergic function in this group. Consistent with this hypothesis, we have previously shown children with ADHD differ from controls in their sensitivity to reward frequency (Tripp & Alsop, 1999). In this study differences in responding were attenuated by methylphenidate, a drug which acts on the dopamine system.

Whatever the cause of the observed age-related decline in sensitivity to reward frequency, this finding has important implications for understanding age related decreases in performance, and for planning rehabilitation and behaviour modification programmes for older adults. Rewards and incentives are thought to affect an individual's motivation which in turn influences performance. If sensitivity to reward frequency decreases with advancing age, then age related declines in performance may reflect reduced motivation and not decreased skill. Increasing the frequency of rewards for older adults may increase motivation and hence performance.

The current findings also call into question the value of external rewards in situations involving skill acquisition (new learning or rehabilitation) and/or behaviour change in older adults. Richer schedules of reinforcement are likely to be required by older adults in situations where skills need to be learned or relearned in the case of rehabilitation. When behaviour change is the goal the number and length of treatment sessions will almost certainly need to be extended and higher overall frequencies of feedback or reward may be necessary.

Furthermore, the reduced sensitivity of older adults to reward frequency, relative to younger groups, raises questions about their comparative sensitivity to reward magnitude and punishment. Experiments designed to assess age-related changes in sensitivity to other aspects of outcomes are clearly called for. The signal-detection paradigm described in the present study offers an appropriate methodology for assessing sensitivity to these other important aspects of outcomes across ages and populations.

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Appendix 1

The following instructions (italics) appeared on the screen. The experimenter read them aloud to the participants, and controlled the pacing of their presentation by responses on the keyboard.

You will see PATTERNS with either more SQUARES. An easy pattern with more squares was displayed on the screen. *Or more CIRCLES.* An easy pattern with more circles appeared on the screen.

You will see only ONE pattern at a time. If there are more SQUARES - press the LEFT key. If there are more CIRCLES - press the RIGHT key.

Each pattern appears for 3 seconds. A small "+" precedes each trial. Like this. A small + appeared on the screen. A practice trial presented the more squares stimulus (easy). *That pattern had more squares so press the LEFT key.* The instructions continued after the subject made the correct response. A second practice trial presented the more circles stimulus (easy). *That pattern had more circles so press the RIGHT key.*

SOMETIMES you are told you are correct and you win 1000 points This looks like— Bonus - 1000 points appeared in the center of the screen.

SOMETIMES you are told nothing. You could be right or wrong

Get as many points as possible. Ready to start the experiment

Remember. Press the LEFT key if more SQUARES. Press the RIGHT key if more CIRCLES. Press any key to begin

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