The Effect of False Positive Feedback on Learning an Inhibitory-Action Task in Older Adults

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Abstract

Background/Study Context: Older adults show a greater response to feedback whilst learning than younger adults. To date this has only been shown for receiving veridical feedback, but there is evidence that suggests that receiving false positive feedback may further enhance learning. We tested the hypothesis that receiving false positive feedback, being told you are preforming better than expected, would be more advantageous for older than younger adults when learning an inhibitory-action task.

Methods: 42 younger and 34 older adults trained to improve their inhibition and response times on the Simon task. They completed 18 training blocks and a retention test two weeks after training. Participants received either false positive feedback or veridical feedback on their performance at the end of each training session and the start of the next session. Those in the false positive feedback group were told they were performing faster than expected.

Results: Both older and younger adults improved their inhibition and response times but receiving false positive feedback did not significantly change their rate of learning on these outcomes. However, false positive feedback did impact on accuracy levels with those receiving this type of feedback making fewer errors. Older adults were slower but more accurate than younger adults, but contrary to our hypothesis they did not benefit more from false positive feedback than younger adults.

Conclusion: This first direct comparison of the effects of false positive feedback on older and younger adults showed that the positive impact of false positive feedback does not decline with age. We also demonstrated that feedback given about one aspect of a skill (in this case speed) may in fact influence another aspect of the skill (in this case accuracy). This suggests that false positive feedback could be used as a motivational tool to enhance cognitive-motor learning in older adults, but care needs to be taken when using this, as the feedback may not affect the element of the skill at which it is targeted.

The Effect of False Positive Feedback on Learning an Inhibitory-Action Task in Older Adults

As population ageing increases the need for older people to learn new skills is becoming more of a necessity that ever before. There are more older people in work, many of whom want training opportunities to learn new skills, particularly around the use of technology. The importance of an active lifestyle in retirement is also recognised, including taking up new hobbies and trying new activities. Therefore, our understanding of how skill acquisition changes with age and how it can be maximised is important. Age-related changes in skill acquisition have been attributed to declines in perceptual, cognitive and physical capabilities (for example, Etnier, Romero, & Traustadottir, 2001; Harrington & Haaland, 1992; McNay & Willingham, 1998), and motor skill learning has been linked to different patterns of activation of subcortical brain structures (Chalavi et al., 2018). Strategies to optimise learning for people of all ages are being investigated and there has been a particular focus on benefits of receiving positive feedback or rewards during skill acquisition. A study by Widmer, Ziegler, Held, Luft, and Lutz (2016) on younger adults showed that receiving feedback and monetary rewards during skill acquisition improved the consolidation of the skill and increased activation in the ventral striatum in the brain. A further study by the same authors found that older adults had higher levels of ventral striatum activation compared to younger adults when their motor performance was rewarded with feedback and money (Widmer, Stulz, Luft, & Lutz, 2017). This suggests that using feedback and rewards during skill learning has a greater impact on older compared to younger adults. Moreover, it has been argued that as older adults are generally biased toward positive information they will learn more from receiving positive than negative feedback (van de Vijver et al., 2015).

In Widmer et al.'s studies the participants received veridical feedback but there is evidence to suggest that manipulating the feedback, by telling people they are performing better than they are, could add an additional advantage. A study by Lewthwaite and Wulf

(2010) on younger adults demonstrated that receiving false positive feedback significantly improved learning on a balance task. A subsequent study on older adults by Wulf, Chiviacowsky, and Lewthwaite (2012) showed a similar trend, although the effect of false positive feedback failed to reach significance levels. However, there were methodological differences between these two balance studies that make them difficult to compare and draw conclusions as to whether the effect of false positive feedback changes with age. Notably, in the study of younger adults (Lewthwaite & Wulf, 2010) the performance measure was the average deviation of the balance platform from the horizontal, whilst in the older adult study (Wulf et al., 2012) the measure was the time spent in balance (within +/- 5 degrees).

False positive feedback clearly has the potential to enhance learning but the extent to which it generalizes to other skills other than balancing that normally decline with age is not known. Deficits in inhibitory control are common in older age and impinge on the control of everyday actions (Potter & Grealy, 2006, 2008; Potter, Grealy, Elliott, & Andres, 2012), and as some of these start to decline in middle age (Potter & Grealy, 2008) it would be interesting to determine whether learning an inhibitory action task is malleable to the effects of false positive feedback. As yet little research has been done in this area although tasks which are predominately cognitive in nature are starting to be studied. For example, Strickland-Hughes, West, Smith, and Ebner (2017) examined the effects of false positive feedback on a memory recognition and recall task and demonstrated that both younger and older participants who received false positive feedback outperformed those who received negative or no feedback.

Performance on the Simon task (Simon & Wolf, 1963), which requires the participant to inhibit making an automatic motor response based on the spatial location of the stimulus and respond according to the colour of the stimulus instead, has been shown to deteriorate with age even after accounting for age-related slowing of information processing speed (Kubo-Kawai & Kawai, 2010; Maylor, Birak, & Schlaghecken, 2011; Sebastian et al., 2013;

van der Lubbe & Verleger, 2002). Performance on this task can be manipulated by both practice and instruction though. For example, Tagliabue, Zorzi, Umilta, and Bassignani (2000) demonstrated that in younger adults the extra time required to inhibit the natural tendency to respond to location rather than colour could be eliminated by practicing incompatible trials one day prior to being tested, and Theeuwes, Liefooghe, and De Houwer (2014) showed that giving specific instructions on how to perform on the trials requiring inhibition, without allowing participants to practice, was sufficient to diminish the Simon effect. This suggests that the Simon effect is well suited to investigating practice effects in both older and younger adults and whether receiving false positive feedback can enhance cognitive-motor skill learning.

The aim of our study was to evaluate whether older and younger adults respond differently to false positive feedback when learning the Simon task. Based on previous findings it was expected that false positive feedback would improve the rate of improvement compared to veridical feedback, and that the effect of false positive feedback would be greater for older adults than the younger adults. It was also predicted that older adults would find the Simon task more difficult than the younger adults; that is they would have slower responses times, longer inhibition times, but their error rates would be comparable to the younger adults.

Method

Participants

Participants were recruited through University websites and by word of mouth. The recruitment advertisements and study information sheet described the study as training to improve reaction time. Ninety volunteered in total and 42 younger (M_{age} = 22.38 years, *SD* = 2.32 years, 28 female, 14 male) and 34 older adults (M_{age} = 71.65 years, *SD* = 4.28 years, 23 female, 11 male) participated. Participants were not eligible if they did not have normal or corrected vision or reported neurological or physical conditions which may have affected their performance on the task. Older participants were screened using the Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975) and those scoring 27 or above were eligible to participate. Ethical approval was granted by the University of Strathclyde and informed consent was obtained.

Apparatus and task

A computerised version of the task devised by Simon and Wolf (1963) was used and the experiment was run and data were collected using E-Prime 2.0. Participants were seated approximately 60 cm from a monitor with a screen (37cm wide, dpi 1400 x 900) on which visual stimuli were displayed and a Cedrus RB-730 response pad was placed centrally on the table in front of them so that participants could rest their index fingers of the response buttons. At the start of each trial a white fixation cross was displayed for 1000ms. A red or green filled circle was then displayed on either the left or the right of the screen and it remained there until the participant responded by pressing the corresponding colour coded key on the response pad. The circles were 3.2cm in diameter and the centre of the circle appeared 13.9cm from the centre in the middle of the screen. The circle was either spatially compatible or incompatible to the location of the button to be pressed. To illustrate, a green circle presented on the left of the screen requiring the left green response button to be pressed would be a compatible trial, whereas a green circle presented on the right of the screen requiring the left green response button to be pressed would be an incompatible trial. Under these conditions the automatic response is to press the button on the same side as the circle regardless of its colour, so when the spatial location and button colour do not match the participant must supress this natural response tendency. This means that participants respond faster when the displayed circle and correct coloured response button are spatially compatible than when they are spatially incompatible. The extra time required to suppress the automatic motor response on the incompatible trials, compared to the fast instinctive response on the compatible trials, is known as inhibition time or the 'Simon effect'. Four measures can be derived from this task; mean response time for compatible (same side) trials, mean response time for incompatible (opposite sides) trials, and mean inhibition time which is the difference between the mean response time for compatible and incompatible trials. Finally, the number of trials where the participant made an error by pressing the wrong coloured button can be measured.

Procedure

On admission to the study participants were randomly assigned to a veridical or a false positive feedback condition. Participants were told that the aim of the study was to see if training would improve reaction times on a computer task. They were instructed that a red or green circle would appear on either the left or right side of the monitor and they should press the corresponding colour-coded key on a response pad as quickly as possible. The layout of the response buttons was randomised; on half of the training sessions the red button was on the right and the green on the left, and for the other half this was reversed. Participants completed six training sessions over the course of two weeks. Each session comprised three blocks, giving 18 blocks in total. Each block had 50 trials, with 35 compatible trials and 15 incompatible trials presented in a random order. Different numbers of compatible and incompatible trials were used to make the task less predictable. There were nearly equal numbers of red and green compatible and incompatible trials in each block. At the start of each training session participants completed 10 warm-up trials and they were allowed to rest for up to two minutes between blocks.

At the end of each training session, and the start of the following training session participants were given feedback on their performance in their previous block of trials. Those in the veridical feedback condition were presented with three bar charts which showed their mean response time for the easy (compatible) trials, mean response time for the difficult (incompatible) trials and number of errors (incorrect responses) they had made during the last trial block in the training session. Those in the false positive feedback condition received response time bar charts which showed additional expected response times for the compatible and incompatible trials. They were told these expected scores were based on the performance of people of the same age doing the same task, but in fact they were fabricated so that each participant was given tailored expected scores that were 18%–22% higher than their actual scores. Thus, the participant's mean response times were always faster than the expected times. They were also presented with the message 'Well done, you were faster than expected'. We chose an increase of 18%–22% based on Lewthwaite and Wulf (2010) and Wulf et al.'s (2012) who used 20% in their studies.

Two weeks after the last training session participants completed a retention test comprising three blocks of 50 trials each.

Results

Errors were defined as the participant pressing the wrong coloured button. For each participant error trials, trials with no response or where the response time was longer than two seconds or less than 100ms were removed. Mean response times for the correct compatible and incompatible trials were then calculated. The difference between these means provided an estimate of the inhibition time for each participant (data are summarised in Table 1). Initial analyses of the data showed there to be no significant differences in responses made by either hand or location of the red and green response buttons.

We predicted that false positive feedback during learning would result in a greater reduction in inhibition times compared to veridical feedback, and there would be a significant interaction between feedback group and age, where the effect of false positive feedback would be greater for older adults than the younger adults. To test these hypotheses we conducted a three-way mixed ANOVA (age (younger and older) x feedback (false positive and veridical) x trial block (1-18)) on the mean inhibition times. As shown in Figure 1a age-related slowing was demonstrated, $F(1, 65) = 41.65$, $p < .001$, $\eta^2_p = .39$ ($M_{younger} = 46.93$ ms, $M_{older} = 88.39$ ms), along with the expected practice effects, $F(17, 1105) = 7.85$, $p < .001$, $\eta^2_p = .11$ ($M_{trial1} = 92.89$ ms, $M_{trial18} = 55.90$ ms). These were maintained at the retention period two weeks later (see Figure 1a). However, the main effect of feedback type was non-significant, $F(1, 65) = .01$, $p = .940$, $\eta^2_p < .01$ ($M_{false\ positive} = 67.41$ ms, $M_{veridical} = 67.91$ ms), as were the interactions that included feedback. A similar pattern of results was found when the ratio of inhibition scores to response scores were analysed.

Similarly, we tested the same hypotheses for differential age effects of false positive feedback on response speed on the compatible trials by running a three-way mixed ANOVA (age (younger and older) x feedback (false positive and veridical) x trial block (1-18)). Figure 1b shows mean scores and again, the main effect of feedback was not significant, $F(1, 65) = .06$, $p = .805$, $\eta^2_p < .01$ ($M_{false\ positive} = 427.84$ ms, $M_{veridical} = 432.35$ ms), and there were no significant interaction effects. As predicted the older adults were significantly slower than younger adults, $F(1, 65) = 107.10$, $p < .001$, $\eta^2_p = .62$ ($M_{younger} = 355.83$ ms, $M_{older} = 524.36$ ms), and response times were significantly faster at the end, indicating learning had occurred, $F(6.56, 426.25) = 14.44$, $p < .001$, $\eta^2_p = .18$ ($M_{trial1} = 477.13$ ms, $M_{trial18} = 400.92$ ms). Further analyses showed that this improvement in speed remained at retention ($M_{blocks16\text{-}18} = 403.06$ ms, $M_{blocks19\text{-}21} = 411.97$ ms, $p > .050$). A similar pattern of results was found on the analysis of the incompatible trials.

We then examined the percentage of errors using a three-way mixed ANOVA (age (younger and older) x feedback (false positive and veridical) x trial (trial blocks 1-18)). We had predicted that the error rates between older and younger adults would be comparable, but as illustrated in Figure 1d there was a significant effect of age $F(1, 72) = 69.73$, $p < .001$, η^2_p

= .50, with older adults making fewer errors than the younger adults (M_{older} = 7.79%, $M_{younger}$ = 19.55%). Contrary to expectation the main effect of feedback type (Figure 1c) was significant, $F(1, 72) = 4.28$, $p = .042$, $\eta^2_p = .06$, with participants who received false positive feedback about their response speed making significantly fewer errors than those who received veridical feedback ($M_{false\ positive}$ = 12.21%, $M_{veridical}$ = 15.13%). There was also a significant main effect of trial, $F(9.52, 685.27) = 2.23$, $p = .017$, $\eta^2_p = .03$, and a post-hoc Tukey test showed there to be a significant increase in errors between trials 1 and 17, and trials 1 and 18 (p <. 050). There were no significant interaction effects.

Analysis of the retention test trials showed that the behaviour persisted with those who received false positive feedback making fewer errors, $F(1,72) = 4.65$, $p = .034$, $\eta^2_p = .06$, older adults making fewer errors, $F(1,72) = 29.17$, $p < .001$, $\eta^2_p = .29$ (Figures 1c and 1d), and there were no significant interaction effects between feedback type and age during the retention trials. Comparing performance during the retention test to the last practice block showed there was a significant increase in errors during the first retention test block, compared to the last practice block ($M_{block18}$ = 14.66%, $M_{block19}$ = 17.07%, p <. 05), but not between the last practice block and the last two retention blocks (block 18 v block 20 and block 18 v block 21, $p > .050$ with Bonferroni corrections applied).

We also examined whether feedback and age impacted on the rate of learning. We calculated the slope for each participant's performance over the practice trials. We then conducted a series of two-way mixed ANOVAs (age x feedback) for the slopes for compatible response times, inhibition times and errors. These analyses showed no significant effects of feedback type or any significant interaction effects with feedback.

Discussion

This direct comparison of providing false positive feedback about response speed to people of different ages learning an inhibitory-action task did not show the advantage we predicted. All the participants learned to respond faster over the course of the study, with a large effect size (.62) for response times and a moderate one (.39) for inhibition times, but false positive feedback did not have a differential impact on either inhibition times or simple response times. Instead those participants who were told they were responding faster than expected for their age were more accurate than those who were not. So rather than the false positive feedback directly influencing speed, the aspect of the task at which it was targeted, it affected the consistency of making accurate decisions. This generalising effect may reflect the nature of the Simon task where the primary, and most cognitively demanding, challenge is to correctly decide which button to press. Receiving feedback that you are performing better than expected may have motivated participants to perform better on the most important element of the task (pressing correctly), rather than pressing quickly. However, contrary to our prediction that false positive feedback would advantage older more than younger adults though, the impact of feedback on accurate decision making was the same for both age groups, and the effect size was small (0.06).

The age difference in error rates, with the older adults making fewer errors than the younger adults (with an effect size of .50), was different to the findings of van der Lubbe and Verlegger (2002), who reported comparable error rates between younger and older adults on a version of the Simon task. The reason for this is not clear but in comparison to van der Lubbe's sample our participants were older (71.65 years compared to 61.20 years) which may account for the differences in findings. Another possible explanation is that the younger, but not older, adults may have adopted a speed-accuracy trade-off strategy. Previous work has shown that younger and older people can have different speed-accuracy trade-off strategies (Strayer & Kramer, 1994) with older adults typically showing a conservative response bias with a shift in emphasis toward accuracy over speed (e.g., Hertzog & Vernon, 1993; Rabbitt, 1979). For a speed accuracy trade-off to be evident in our data there needed to be a reduction in speed, which we found, and an increase in errors which we also found. However, the significant increase in errors only occurred in the last two training blocks. Had age or feedback impacted on the use of a speed-accuracy trade-off then significant age x trial and feedback x trial interactions would have been found. This was not the case. This finding is in contrast to Touron and Hertzog (2014) who investigated the effect of receiving speed or accuracy feedback on a word-pair matching task. They found that older participants who received accuracy feedback used a retrieval strategy more often than those who did not receive accuracy feedback. They also found that feedback about response speed did not affect strategy use. Our data suggest that false positive feedback did change the strategy used, but it did so equally for both age groups. That is whilst false positive feedback promoted accuracy but did not affect speed, veridical feedback resulted in less accurate performance but not an increase in speed.

The lack of an age difference relating to feedback was unexpected given Widmer et al.'s (2017) report that activation of the ventral striatum following reward on a motor task was greater in older compared to younger adults. However, the task that Widmer et al. studied was not cognitively demanding. Participants were asked to flex and extend their hand at the wrist, and these movements were tracked so that they moved a cursor on a computer screen. Each participant's task was to move their non-dominant hand so as to make a semi-circular arc on the screen at a speed that was dictated by a clock. In contrast the Simon task is cognitively demanding, especially for older adults, and in this respect our findings are more in line with Strickland-Hughes et al. (2016). They found that younger and older adults responded similarly to false positive feedback on a memory recognition and recall test, even though the younger adults outperformed the older adults on both recall and recognition overall. Similarly, and in line with Strickland-Hughes et al. (2016), the older adults in our study showed age-related declines in that they were slower than the younger adults in their response times and had longer inhibition times whilst responding similarly to false positive feedback. It appears that the addition of false positive feedback in our study affected just one cognitive aspect of the task, maintaining correct decision making, rather than the speed of decision making or the speed of motor response.

There are well documented ageing effects on performance on the Simon task, and an fMRI study by Sebastian et al. (2013) showed that older adults recruit additional brain regions during the Simon task (the left prefrontal and bilateral caudate nucleus) to compensate for their lack of interference inhibition. So whilst it could be expected that the brain structures associated with motor learning recruited by younger and older adults are likely to have differed in our study, the effects of false positive feedback in modulating the accuracy of responses remained the same for both ages even if speed-accuracy trade-off strategies were adopted. Further research is required to determine the interactions between the brain regions associated with receiving false positive feedback and those regions associated with making accurate motor response decisions, but our findings suggest that even if these differ between older and younger adults the impact that false positive feedback has on the performance of a challenging inhibition task does not decline with age. The extent to which this would generalise to other less demanding cognitive action tasks also needs to be established, as it may be that on easier tasks an age-related advantage from feedback may be evident.

A limitation of this study is that we did not measure perceived self-efficacy for the task at the start of the study. One of the ways in which false positive feedback may work is by improving self-efficacy or self-confidence. If this is the case then it may be more beneficial for those who are lower in self-efficacy at the start of learning compared to those who are higher. So whilst our participants were randomly assigned to groups, and performance on the task did not significantly differ across the groups on the first trial, we are not able to demonstrate that the groups were comparable in their initial levels of perceived self-efficacy. It may also be that our sample, who self-selected to participate, were relatively high in self-efficacy and if this were the case it may have impacted on the extent to which false positive feedback could have influenced their learning. Future research could assess this by comparing groups of older and younger adults with low and high confidence/self-efficacy, and see if those lowest in efficacy improve the most. It would also be interesting to test whether self-efficacy mediates the relationship between false positive feedback and performance.

The higher degree of variance in the scores of the older groups was not unexpected and reflected some of the participants experiencing more age-related changes than others. However, it is possible that a number of higher performing older adults in our sample could have contributed to the lack of an effect of feedback. Whilst our older participants did demonstrate significant age-related slowing in their response and inhibition times, studying people who are more than eighty years old may provide a better test of whether there is an old age advantage of false positive feedback, particularly if they demonstrate a lack of confidence and self-efficacy. It should be noted though that the mean age of our older sample (71.65 years) was very similar to the sample in Wulf et al.'s (2012) study (71.1 years) where a clear effect of false positive feedback on skill learning was shown.

In conclusion, this first direct comparison of older and younger adults on the effects of receiving false positive feedback on performance whilst practising a inhibitory-action task indicate that the benefits derived from this type of feedback do not decline with age. In fact in terms of accuracy the older adults who received false positive feedback outperformed all the other groups. Given the importance of skill learning for older adults in work or actively seeking new challenges in retirement, the finding that false positive feedback could be used as a motivational tool to enhance cognitive-motor learning is important. However, given our finding that the feedback did not affect the element of the skill it was targeted at further work is needed to understand how best to use it.

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Table 1. Means and SDs for inhibition times (ms), response times on compatible trials (ms) and the percentage of errors made by younger and older adults in the false positive or veridical feedback conditions during the first practice trial block (start of practice) the last practice trial block (end of practice) and the first block completed at retention.

	Start of practice		End of practice		Retention	
	M	SD	M	SD	M	SD
Inhibition times						
Young False Positive	58.43	30.63	38.62	21.03	43.95	20.96
Young Veridical	67.76	21.50	35.14	19.30	46.00	16.58
Older False Positive	128.59	49.52	79.18	49.97	75.94	55.32
Older Veridical	107.65	60.95	65.35	35.81	76.18	43.20
Response times						
Young False Positive	361.81	59.89	325.62	56.86	335.76	75.90
Young Veridical	349.81	45.54	311.05	32.24	315.67	39.63
Older False Positive	579.00	131.19	472.12	86.66	475.94	101.48
Older Veridical	555.41	113.75	478.06	113.12	498.06	104.96
% Errors						
Young False Positive	16.10	10.36	18.95	11.52	19.14	12.06
Young Veridical	14.38	8.98	22.29	6.67	27.62	12.94
Older False Positive	6.71	4.52	6.59	6.55	9.88	8.14
Older Veridical	8.94	9.65	10.82	7.18	11.65	6.75

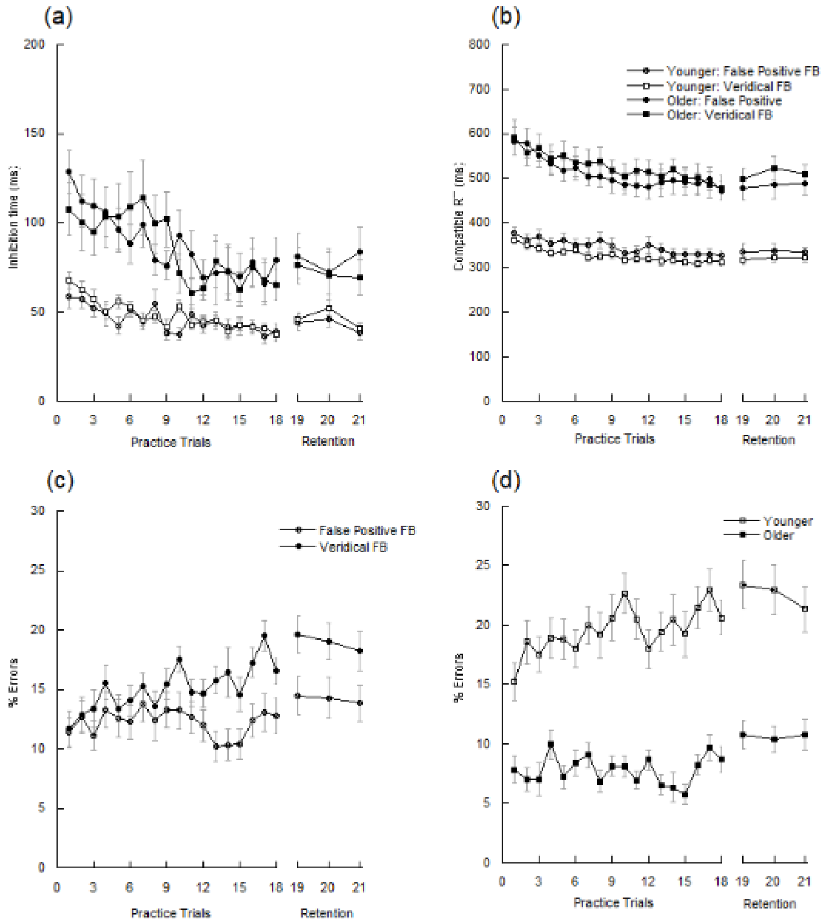

Figure 1.

Means and SEs for (a) inhibition times and (b) response times on compatible trials in each of the four conditions, (c) the percentage of errors made under the false positive and veridical feedback conditions during practice and retention and (d) the percentage of errors made by younger and older adults during practice and retention.