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Evidence for Short-term, but not Long-term Transfer Effects in the Temporal Preparation of Auditory Stimuli

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Abstract

Starting procedures in racing sports consist of a warning (e.g. 'Set') followed by a target (e.g. 'Go') signal. During this interval (the foreperiod), athletes engage in temporal preparation whereby they prepare to respond to the target as quickly as possible. Despite a long history, the cognitive mechanisms underlying this process are debated. Recently, S. A. Los, W. Kruijne, & M. Meeter (2014, Outlines of a multiple trace theory of temporal preparation, *Frontiers in Psychology, 5*: 1058) suggested that traces of previous temporal durations drive temporal preparation performance rather than the traditional explanation that performance is related to the currently perceived hazard function. Los and colleagues used visual stimuli for the warning and target signals. Since racing sports typically rely upon auditory stimuli, we investigated the role of memory on temporal preparation in the auditory domain. Experiment 1 investigated long-term transfer effects. In an acquisition phase, two groups of participants were exposed to different foreperiod distributions. One week later, during a transfer phase, both groups received the same distribution of foreperiods. There was no evidence for transfer effects. Therefore, Experiment 2 examined short-term transfer effects in which acquisition and transfer phases were completed in the same testing session. There was some evidence for transfer effects, but this was limited suggesting that there may be modality-specific memory differences.

Keywords: Temporal Preparation, Foreperiod, Memory, Multiple Trace Theory, Hazard Function, Racing Sports

Evidence for Short-term, but not Long-term Transfer Effects in the Temporal Preparation of Auditory Stimuli

In racing sports, starting procedures typically consist of an official giving a warning stimulus (e.g. “Set”), followed by a target stimulus (e.g. gun shot) indicating the start of the race. The interval between the warning (S1) and target (S2) stimulus is the foreperiod during which athletes engage in *temporal preparation,* the process whereby they get ready to respond to the target stimulus as quickly as possible (Dalmaijer, Nijenhuis, & Van der Stigchel, 2015). Temporal preparation has been widely studied in lab-based reaction time (RT) tasks and it is well-documented that RT is affected by both the duration and distribution of foreperiods (Niemi & Näätänen, 1981). RT decreases when foreperiod increases (i.e. the variable foreperiod effect; Woodrow, 1914) and RT-foreperiod function are affected by foreperiod distributions. Anti-exponential distributions (i.e. more frequent occurrence of longer foreperiods) reveal a steep decrease in RT as foreperiod increases (e.g. Los, Kruijne, & Meeter, 2017) whereas exponential distributions (i.e. more frequent short foreperiods) result in a flat RT-foreperiod functions (e.g. Trillenberg, Verleger, Wascher, Wauschkuhn, & Wessel, 2000).

Despite the long history and the obvious real-world implications (e.g. in racing sports and many tasks requiring responding quickly to alarms etc), the cognitive mechanisms underlying temporal preparation are still debated. There are two current competing hypotheses, the first is the traditional, and widely held, view that participants use awareness of the hazard function, namely the increasing conditional probability that the target will occur to drive preparation, given that it has not already (Luce, 1986). The current hazard successfully predicts the RT-foreperiod function of participants under different variable-foreperiod designs. For example, the variable foreperiod effect (a decrease in RT as foreperiod increases) corresponds to the increase in hazard because the probability of the target occurring increases as foreperiod lengthens (Cui, Stetson, Montague, & Eagelman, 2009) and the hazard remains constant when participants are exposed to exponential foreperiod distributions which directly maps onto the flat RT-foreperiod function (e.g. Trillenberg, Verleger, Wascher, Wauschkuhn, & Wessel, 2000). This view proposes that participants optimise their state of preparation by accessing, updating, and applying the hazard function as it changes over time.

The hazard function explanation of temporal preparation has been criticised because it does not have a cognitive basis (Los, 2013). Specifically, participant's ability to acquire knowledge and update their preparation based on the changing hazard is not well explained. In addition, although the hazard function can explain several RT-foreperiod functions, it cannot explain the sequential effect that RT on the current trial is affected by both the current foreperiod and the immediately preceding foreperiod(s). Sequential effects show that RT on a current trial is longer and shorter when the preceding foreperiod was longer and shorter than the current foreperiod, respectively, which results in the asymmetry that characterises the sequential effect.

As an alternative explanation to the hazard function, Los et al., (2014) proposed the multiple trace theory of temporal preparation (MTP). This theory assumes that, on any given trial, inhibition is applied to prevent premature responses following the presentation of the warning signal and activation is applied to support the response to the target. These inhibition and activation profiles are then stored as memory traces. During the foreperiod on a subsequent trial, these actions and temporal profiles are retrieved and aggregated across memory traces to determine the current preparatory state. In support of their theory, Los et al., (2017) demonstrated transfer effects of different foreperiod distributions, showing that previous timings contributed to current temporal preparation within one testing session. Two groups of participants were presented with different foreperiod distributions, either exponential or anti-exponential, in an acquisition phase. Immediately after this phase, participants were informed about the distributions they had just experienced and that they would be exposed to a uniform distribution of foreperiods in the following block. Both groups demonstrated transfer effects indicative of a role of memory traces from the acquisition phase influencing performance in the transfer phase. Specifically, there was a flatter RT-foreperiod distribution for the exponential group and faster RT at longer foreperiods for the anti-exponential group. This result directly contradicts hazard-based explanations because participants should be able to quickly tune in on the prevailing hazard function and therefore, no transfer between blocks would be expected. Subsequently, Mattiesing, Kruijne, Meeter, and Los (2017) conducted a study in which the acquisition phase (when groups were presented with different foreperiod distributions) was completed one week prior to the transfer phase (when both groups were presented with uniform distributions). There was still evidence for transfer effects after a one-week delay suggesting that long term memory plays a role in driving temporal preparation. Taken together, these findings demonstrate that old timing experiences contribute to current temporal preparation, which supports a key prediction of MTP.

Transfer effects cannot be accounted for by models of temporal preparation based on the hazard function (e.g. Coull, Cheng, & Meck,2011; Cui, Stetson, Montague, & Eagleman, 2009; Vallesi & Shallice, 2007) because participants used neither the information provided at the start of the transfer session, nor their initial experiences during the transfer session to quickly adjust to the new foreperiod distribution and resulting hazard function. Further support for MTP comes from the finding that transfer effects were considerably reduced in the transfer session after a one week interval. Los et al., (2014) explain that this is due to the newer memory traces carrying more weight than older traces in their contribution to preparation on the current trial. MTP is therefore strengthened because it relies on the well-established principles of memory with recent memories more accessible than older ones.

If the processes underlying transfer effects are general encoding and memory principles, then we would expect transfer effects to occur when stimuli from other modalities are used. However, to date, research directly testing MTP has only been conducted in the visual domain. Previous research on temporal preparation has revealed conflicting results from different modalities. Using a constant foreperiod design (each experimental block only contained one foreperiod duration), Sanders and Wertheim (1973) reported an interaction between the effects of signal modality and foreperiod duration on RT. Although an increase in RT between foreperiods of 1 and 5s was observed in the visual domain, which is the typical finding in studies using the constant foreperiod design, there was no effect in the auditory domain. A possible explanation is that auditory signals are more alerting, and therefore draw transient attention and could compensate for the negative effects of a more deficient response preparation at longer foreperiods (Sanders & Wertheim, 1973). Other studies have, however, found clear effects of foreperiod duration on auditory RT tasks (e.g. Karlin, 1959; Sanders, 1965; Trumbo & Gaillard, 1975) which suggests that the effect is dependent upon the state of other variables with the studies reported using different stimulus intensities which could be a relevant variable. Bernstein, Chu, Briggs, and Schurman (1973) reported a significant interaction between foreperiod duration and intensity of auditory signals, whereas the intensity of visual stimuli did not interact with foreperiod duration (see also, Sanders, 1975). Taken together, there is conflicting evidence regarding the effect of modality (i.e. visual versus auditory) on foreperiod effects. While sequential effects have been shown with auditory stimuli (e.g. Steinborn, Rolke, Bratzke, & Ulrich, 2008; Valessi, Shallice, & Walsh, 2006; Van der Lubbe, Los, Jaśkowski, & Verleger, 2004), it remains an open question whether these modality differences might manifest in longer-term memory processes, as implied by MTP. There are known differences in our short-term (Bigelow & Poremba, 2012) and long-term (Cohen, Horowitz, & Wolfe, 2009) retention of auditory and visual stimuli, with auditory memory being inferior to visual memory. Inferior auditory memory may result in weaker representations of temporal durations demarked by auditory signals, and thus weaker or non-existent transfer effects. Given cross-modality differences in the temporal preparation literature, research is required to investigate transfer effects in the auditory domain as a direct test of MTP. According to MTP, the same inhibition and activation should be applied on a given trial and then stored as memory traces for auditory stimuli, thus resulting in the same qualitative pattern of results indicative of transfer effects. Moreover, since racing sports and many alerting systems commonly rely upon auditory stimuli (e.g. sprint, speed skating, medical alarms) research exploring the role of memory in temporal preparation in the auditory domain is required given the practical implications.

We conducted two replication experiments. Experiment 1 replicated Mattiesing et al., (2017) to investigate whether long term transfer effects persisted a week later with auditory stimuli. We hypothesised that there would be evidence for transfer effects because, according to MTP, memory traces for auditory stimuli should also be stored and then retrieved to determine the preparatory state on the current trial in the same manner as visual stimuli. Since, contrary to our expectations, there was no evidence for transfer effects in Experiment 1, Experiment 2 replicated Los et al., (2017) to explore whether transfer effects were observed in the same testing session. We found some evidence for transfer effects, but these disappeared relatively quickly.

Experiment 1

This study was a close replication of Mattiesing et al. (2017) and was preregistered: https://osf.io/4ucvk/?view_only=96f3b047bb974d2aa3f13a8caa0e8a62

Method

Participants. Twenty-eight students (M = 25.57, SD = 3.75; 25 female) from the University of Bristol volunteered to participate in the experiment. This gave us at least an 80% chance of obtaining an effect size of partial η^2 = 0.34 at an alpha level of .05, based on data from Mattiesing et al. (2017). All participants had normal hearing. Participants were randomly assigned to an Anti-exponential Group (N = 14) or an Exponential Group (N = 14). In order to motivate participants to respond quickly, the two fastest participants in each condition won £50 or £25, respectively.

Design. A mixed design was used with foreperiod (400, 800, 1,200, or 1,600 ms) a within-subject factor, and training distribution (exponential or anti-exponential) a between-subject factor. In the exponential condition the ratio of foreperiods was 8: 4: 2: 1 (majority short durations) and in the anti-exponential 1: 2: 4: 8 (majority long durations). The training session involved five blocks, both the Exponential and Anti-exponential Group received a uniform distribution of foreperiod durations in the first block, followed by four blocks of either exponentially or anti-exponentially distributed duration, respectively. In the transfer session, one week later, both groups completed four blocks of uniformly distributed foreperiod durations. The dependent variables was RT.

Procedure. Participants were tested in groups of two to four. Participants sat in front of a monitor connected to a PC running custom written software (ensuring low-latency timings) to present the warning and target signals via Sony MDR-ZX110 stereo headphones. A standard USB mouse was used to collect responses to the target.

Stimuli consisted of sine-wave tones, which were ramped at onset for 50ms. Each trial consisted of a warning signal, a 540 Hz tone played for the duration of the foreperiod, followed immediately by a target signal, a 1,000 Hz tone played for 2,000ms or until participants gave a response. Participants were told to respond as fast as possible upon detecting the onset of the target by clicking the left mouse button. There was then a 1,500 ms inter-trial interval. Each block consisted of 120 trials. After each block participants were given their mean RT and asked to write this down onto a piece of paper to keep participants motivated to respond as quickly as possible.

In the acquisition phase (session 1), participants completed five blocks of the experimental task lasting approximately 40 minutes. During this session, they were given no information about the distribution of foreperiod durations. One week later, on arrival at the transfer phase (session 2), participants were told about the distributions they had received in the acquisition phase and informed that in each block of the transfer phase, short and long intervals would occur equally often. They then completed four blocks of the experimental task which lasted approximately 30 minutes. Participants were fully debriefed after the second session.

Results and Discussion

For all participants, the first trial of each block and trials with RTs shorter than 150 ms (3%) or longer than 800 ms (<1%) were removed and not analysed further.

A mixed ANOVA, with foreperiod included as a linear (1 degree of freedom) within-subject factor and group as a between subject factor, was run on each block to investigate the effect of group of the slope of the RT-foreperiod function. There was a main effect of foreperiod in Block 1, $F(1, 26) = 38.63$, $p < .001$, $\eta^2_p = .598$, which showed a decrease in RT as a function of foreperiod. Temporal preparation was initially equivalent in both groups, demonstrated by no main effect of group, and no interaction between group and foreperiod ($F = 0.91$). In Blocks 2 – 5 there was a significant interaction between foreperiod and group, with the weakest interaction in Block 2, $F(1, 26) = 46.03$, $p < .001$, $\eta^2_p = .639$. The exponential and anti-exponential group displayed an approximate flat and steep RT-foreperiod function respectively (see Figure 1, panel a). One week later, both groups received the uniform distribution and there was no evidence for transfer, which would be evident as an interaction between group and foreperiod across all four blocks (see Figure 1), the largest effect, for Block 3, was $F(1, 26) = 3.12$, $p = .089$, $\eta^2_p = .107$. Nonetheless, the slopes of the anti-exponential group were slightly steeper than those of the exponential group and so we conducted an exploratory analysis. We first averaged the data across all four transfer blocks, which still did not provide evidence of a transfer effects, with a non-significant interaction between group and foreperiod $F(1, 26) = 1.61$, $p = .215$, $\eta^2_p = .058$. Next, because we cannot interpret a null effect under the standard frequentist ANOVA as evidence for a lack of effect, we also conducted an independent samples Bayesian t-test (using JASP, JASP Team, 2018) comparing the anti-exponential and exponential condition for the 400 ms foreperiod condition (where in the acquisition phase the differences were largest) for each transfer block. Neither the individual t-tests for each block (all $BF_{10} < 0.62$), nor a t-test on the data averaged across blocks, $BF_{10} = 0.41$, provided any evidence for a difference between the groups for the 400 ms foreperiod. However, all the evidence was inconclusive when it came to determining support for the null hypothesis (no transfer effect, all $BF_{10} > 0.36$, typically a $BF_{10} < .33$ is taken as evidence for the null). However, the Bayesian analysis is consistent with the frequentist analysis in that neither provide any evidence for a transfer effect. We take this as evidence that if there is a transfer effect, it is very small in this experiment.

An exploratory analysis was conducted to test for sequential effects and, investigate whether classical temporal preparation effects were present in our data A 4 (current foreperiod (FP): 400, 800, 1200, 1600) x 4 (preceding foreperiod (FP_{n-1}): 400, 800, 1200, 1600) within subjects ANOVA was conducted (results were collapsed across group and block). There was a main effect of current foreperiod $F(1, 26) = 16.65$, $p < .001$, $\eta^2_p = .381$, with a decrease in RT as a function of foreperiod. There was also a main effect of preceding foreperiod, $F(1, 26) = 27.45$ $p < .001$, $\eta^2_p = .514$, with an increase in RT as a function of previous foreperiod. Importantly, there was an interaction between previous and current foreperiod, $F(1, 26) = 26.86$, $p < .001$, $\eta^2_p = .508$, showing that FP_{n-1} strongly modified short foreperiods but not long foreperiod, thus demonstrating the classic sequential effect. A three-way interaction between group, current foreperiod and preceding foreperiod was also revealed, $F(1, 26) = 4.99$, $p = .034$, $\eta^2_p = .161$, but there were no other significant main effects of interactions (all $F < 1.62$, $p > .214$). This typical pattern of results confirms that, although our RTs were very fast, our experimental task was suitable to detecting at least shorter-term sequential effects, and is therefore comparable in this regard to other studies in the literature.

It is possible, given the relatively fast responding in the transfer phase, that RTs are at floor, and therefore, we are unable to detect an interaction between group and foreperiod. However, the mean RT for the exponential group is longer in the transfer than the acquisition phase, and the interaction is also driven by the relatively slow responding to short foreperiods in the anti-exponential condition, making an explanation in terms of a floor effect for the lack of interaction unlikely. Moreover, if there was a floor effect then we would not expect to find the sequential effects that are present in the data.

Session		Session 1					Session 2			
Block		1	2	3	4	5	6	7	8	9
Group	Anti-exp	Uni	Anti-exp	Anti-exp	Anti-exp	Anti-exp	Uni	Uni	Uni	Uni
	Exp	Uni	Exp	Exp	Exp	Exp	Uni	Uni	Uni	Uni

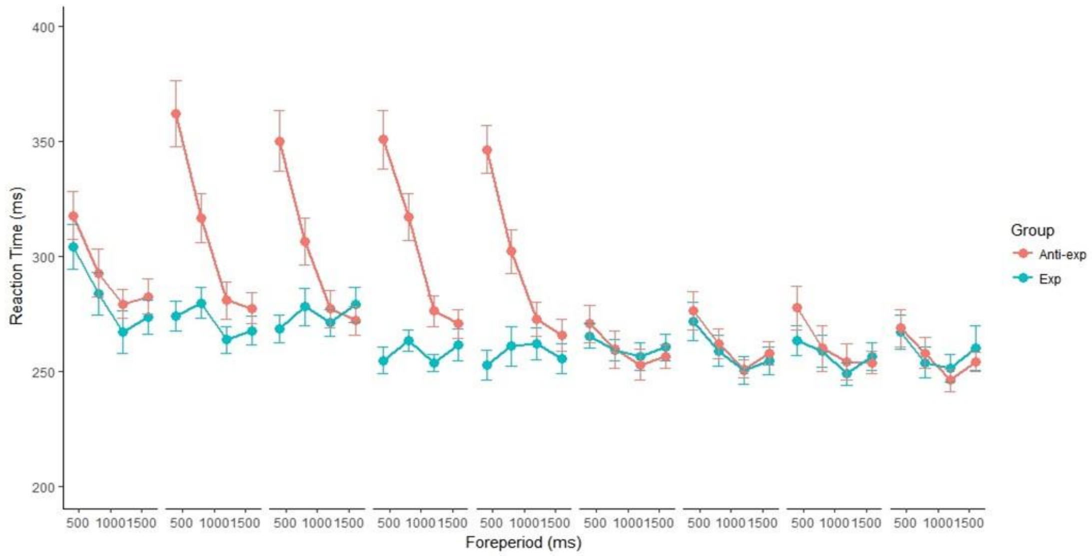

Figure 1. Mean response time as a function of foreperiod, group, and block. Error bars represent between subject ±1 standard error.

The lack of transfer effects does not support MTP's claim that long-term memory drives temporal preparation in the auditory domain, which could indicate modality-specific effects. Previous research has shown some evidence for cross-modality differences in temporal preparation between the visual and auditory domain (e.g. Bernstein et al., 1973; Sanders & Wertheim, 1973). It is possible, therefore, that there are cross-modality differences in temporal preparation. Specifically, auditory stimuli may be more alerting and, therefore, may more easily capture attention compared with visual stimuli, which may result in weaker memory representations for auditory stimuli as less attention has been directed toward them (in order to detect them; e.g. Bigelow & Poremba, 2012; Cohen et al., 2009). Los et al. (2017) initially tested the predictions of MTP within a single testing session. Although we did not find evidence for transfer effects in the auditory domain at a one-week interval, a replication of Los et al. (2017), is warranted to further explore the role of memory in driving temporal preparation. Specifically, it is possible that auditory traces are encoded as memory traces but, due to the alerting nature of the stimuli, the effects are more short-lived compared to the visual domain.

Experiment 2

This study was a close replication of Los et al. (2017)and was preregistered on the OSF: https://osf.io/qa2ep/?view_only=2d20c656659844cf825416f297c376e4

Participants. Forty-seven participants (*M* = 25.06, *SD* = 4.64; 20 male, 27 female) volunteered to take part in the experiment. This gave us at least an 80% chance of obtaining an effect size of partial η^2 = 0.21 at an alpha level of .05, based on data from Los et al. (2017). All participants had normal hearing and gave informed written consent. Participants were randomly assigned to the Exponential (N = 23) or Anti-exponential group (N = 24). The fastest two participants from each condition were given £50 or £25 respectively.

Design and Procedure.

All aspects of the experiment were identical to Experiment 1, with the following exceptions. Participants completed five blocks of the task lasting approximately 40 minutes. In the first block, both the Exponential and Anti-exponential Group received a uniform distribution of foreperiod durations followed by two blocks of either exponentially or anti-exponentially distributed duration, respectively. Following block 3 participants were informed about the distributions that they had received in the preceding blocks and informed that in blocks 4 and 5 short and long intervals would occur equally often. Blocks 4 and 5 contained uniformly distributed fore period durations.

Results and Discussion

For all participants, the first trial of each block and trials with RTs shorter than 150ms (5%) or longer than 800ms (<1%) were removed and not analysed any further.

A mixed ANOVA, with foreperiod included as a linear (1 df) within-subject factor and group as a between subject factor, was run on each block to investigate the effect of group of the slope of the RT-foreperiod function. There was a main effect of foreperiod in Block 1, $F(1,45) = 55.41$, p <

.001, η^2_p= .552, which showed a decrease in RT as foreperiod duration increased. Performance was initially equivalent in both groups, demonstrated by no main effect of group and no interaction between group and foreperiod (F = 0.84). In Blocks 2 and 3, there was a significant interaction between foreperiod and group, minimal $F(1, 45) = 49.83$, $p < .001$, η^2_p= .525 (Block 2). The exponential and anti-exponential group displayed an approximate flat and steep RT-foreperiod function respectively (see Figure 2). In Blocks 4 and 5, both groups received the uniform distribution. There was evidence for an interaction between group and foreperiod in Block 4, $F(1, 45) = 5.88$, p = .019, η^2_p= .116, indicating transfer. There was, however, no evidence for transfer effects in Block 5, $F(1, 45) = 1.81$, $p = .185$, η^2_p= .039, although the direction of the results are consistent evidence for at best a small transfer effect.

In line with Experiment 1, an exploratory analysis into sequential effects was conducted. There was a main effect of current foreperiod $F(1, 45) = 48.27$, $p < .001$, η^2_p= .518, with a decrease in RT as a function of foreperiod. There was also a main effect of previous foreperiod, $F(1, 45)$ = 61.29, $p < .001$, η^2_p= .576, with an increase in RT as a function of previous foreperiod. There was, again evidence for sequential effects, demonstrated by an interaction between previous and current foreperiod, $F(1, 45) = 121.06$, $p < .001$, η^2_p= .729. There was also an interaction with group and current foreperiod, $F(1, 45) = 14.64$, $p = .034$, η^2_p= .245 but no other significant main effects or interactions were revealed (all $F < 1.0$, $p > .323$).

This study reveals some evidence for transfer effects, but these are short-lived and only maintained for a single block. Mattiesing et al. (2017) noted that reduced transfer effects for later blocks still fits with predictions of MTP, because recent memory traces carry more weighting than older traces in their contribution to preparation on the current trial (Los et al., 2014). Despite evidence for a role of memory in temporal preparation, the strength of effect is smaller than in the visual domain which may indicate some cross-modality differences in how memory is encoded and retrieved.

Block		1	2	3	4	5
Group	Anti-exp	Uni	Anti-exp	Anti-exp	Uni	Uni
	Exp	Uni	Exp	Exp	Uni	Uni

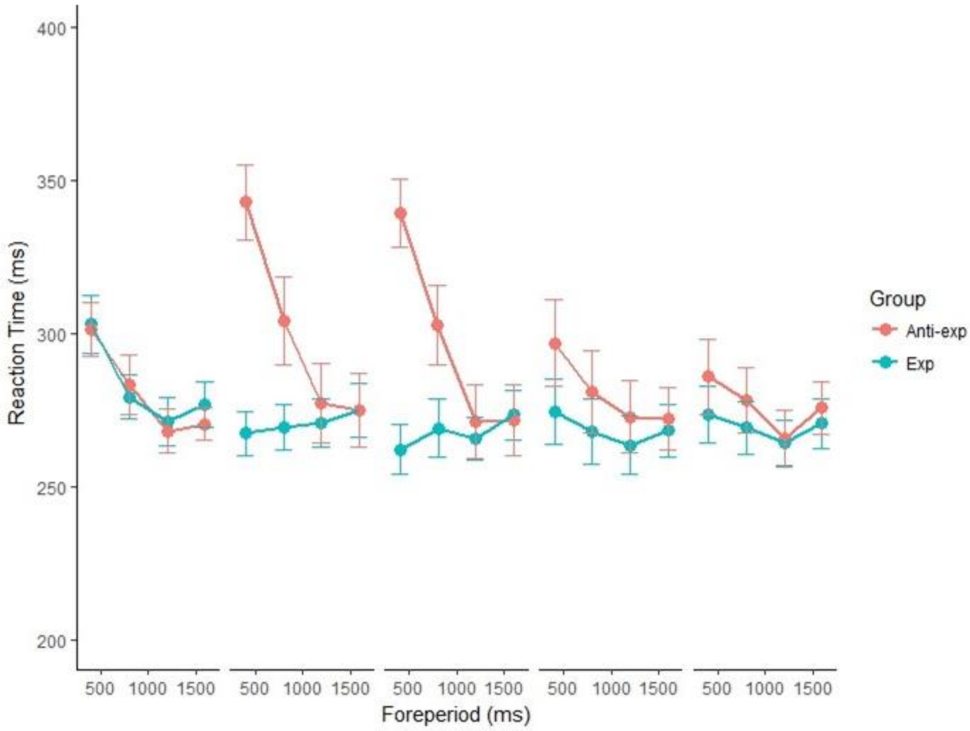

Figure 2. Mean response time as a function of foreperiod, group, and block. Error bars represent between subject ±1 standard error.

Discussion

Two experiments, replicating Mattiesing et al. (2017) and Los et al. (2017) respectively, were conducted to test whether there was evidence for a role of long term memory in the temporal preparation of auditory stimuli. Experiment 1 revealed no evidence for transfer effects after a one-week delay whereas Experiment 2 revealed some evidence for transfer effects, although these were short-lived, restricted to a single block. Taken together these findings provide some support for MTP but may indicate modality-specific effects in temporal preparation, with weaker transfer effects for auditory stimuli. One of the strengths of MTP is the reliance on well-established general memory and encoding principles, however, the evidence from our two experiments may mean a more specialist mechanism is needed to account for modality differences. Although hazard function accounts could account for the findings in Experiment 1, the transfer effects in Experiment 2 cannot be accounted for because the hazard function is derived from the current distribution of foreperiods and, therefore, essentially has no memory of previous durations so cannot account for transfer or sequential effects (which were observed in both Experiments 1 and 2).

Currently, MTP has no explicit mechanism to account for modality effects, but our results suggest that this possibility requires consideration. Auditory signals have been shown to be more alerting leading to faster RTs (Sanders & Wertheim, 1973). It is therefore possible that auditory signals require less effortful sustained attention to elicit a response. If less sustained attention is applied to a stimulus, it is possible that they are encoded less strongly into memory and are therefore likely to be vulnerable to decay or interference over a much shorter time scale (Mulligan, 2008) leading to weaker or non-existent transfer effects. Note, this weaker encoding may still result in strong acquisition effects (as we observed in both experiments) and transfer effects across one block, if there is greater reliance on more recently encoded foreperiods (as also suggested by Los et al., 2014). Under certain circumstances, tactile stimuli are also thought to be more alerting than visual stimuli. Research using tactile stimuli could further explore possible modality-specific differences in temporal preparation. This has clear theoretical implications but is also warranted given the increasing use of tactile stimuli in warning signals (Murata, Kuroda, & Karwowski, 2017) and limited research exploring modality shifts between trials (e.g. Steinborn, Rolke, Bratzke, & Ulrich, 2010). Further research is required to understand how memory might be involved in each of these domains.

Another possible explanation for the limited evidence for transfer effects in our experiments is subtle differences in the response procedure used in our experiment and those of Mattiesing et al. (2017) and Los et al. (2017). Both Los et al. (2017) and Mattiesing et al. (2017) used a choice-RT task to dissuade participants from anticipatory responding. We chose to use a simple RT task to avoid any effects of the decision-making process. Since the literature typically reveals similar foreperiod effects for both choice and simple RT tasks (Frith & Done, 1986; Steinborn & Langner, 2012), it can be assumed that MTP should generalise and therefore, this difference should not have eliminated any transfer effects. Nonetheless, it could be argued that a choice-RT task requires greater levels of attention, thus also strengthening the memory for the stimuli, and leading to larger transfer effects. Further experiments will be needed to conclusively rule out subtle methodological differences leading to divergent results, rather than modality differences in memory strength. It is also possible that using a filled foreperiod rather than a blank foreperiod contributed to different results, dependent on modality. The filled-FP effect describes a decrease in performance when the interval between the warning and target signal is filled, rather than blank (e.g. Terrell & Ellis, 1964; Baumeister and Wilcox, 1969). The *distraction-during-FP hypothesis* suggested that participants attentional focus is directed away from the experimental task resulting in an increase in RT, with concurrent stimulation in the auditory domain drawing on more of the attentional resource (Steinborn and Langner, 2011). Steinborn and Langner (2011) showed that an auditory-filled FP resulted in an increase in RT for long-FP trials, compared with a blank-FP. This selective effect on long-FP could potentially mask transfer effects and, therefore, more research exploring the effect of blank- compared with filled-FPs is required.

A final possibility is that the acquisition of the foreperiod distributions was weaker in our experiments compared with previous studies. However, comparing our effect sizes in the acquisition phase with those for the relevant experiments in compared with Mattiesing et al. (2017) and Los et al. (2017) shows that our acquisition effects were numerically bigger, suggesting that the lack of transfer effects cannot be attributed to a weaker acquisition effect.

In conclusion, we present two experiments, using auditory signals, that present limited evidence regarding the role of long term memory in temporal preparation. Experiment 1 found no evidence for transfer effects of foreperiod distributions which does not fit with MTP.However, Experiment 2 provided some support for MTP, with transfer effects emerging, although they were very short-lived. Further research is needed to explore possible modality-specific effects on the role of memory in driving temporal preparation to inform and, perhaps, refine MTP, or whether the difference between a choice-RT and simple-RT is crucial (which would still be problematic for MTP). Such research could also have practical implications with the emergence of transfer effect suggesting that the foreperiods on which athletes train could directly impact their reaction time on race day.

Footnotes

[1]We thank Wouter Kruijne for suggesting this analysis.

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