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Subjective time perception in musical imagery: An fMRI study on musicians

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Abstract

The cognitive preparation of an operation without overt motor execution is referred to as imagery (of any kind). Over the last two decades of progress in brain timing studies, the timing of imagery has received little focus. This study compared the time perception of ten professional violinists' actual and imagery performances to see if such an analysis could offer a different model of timing in musicians' imagery skills. When comparing the timing profiles of the musicians between the two situations (actual and imagery), we found a significant correlation in overestimation of time in the imagery. In our fMRI analysis, we found high activation in the left cerebellum. This finding seems consistent with dedicated models of timing such as the cerebellar timing hypothesis, which assigns a "specialized clock" for tasks. In addition, the present findings might provide empirical data concerning imagery, creativity, and time. Maintaining imagery over time is one of the foundations of creativity, and understanding the underlying temporal neuronal mechanism might help us to apprehend the machinery of creativity per se.

KEYWORDS
creativity, dedicated model, fMRI, left cerebellum, mental imagery, musical imagery, timing, time perception

INTRODUCTION

Our experience of life is shaped by time, the currency of life. Furthermore, when the relationship between time and the brain is considered, it is necessary to take subjective time into account. We find it endlessly fascinating to examine how time is perceived – how it feels to us as individuals – because time keeps surprising us: the moment you return home from a good holiday, it feels as though you have been away for centuries. How is it possible to feel as though time has passed so quickly? In what way do we interpret the length of time?

Psychologists and neuroscientists are also working on subjective time perception. They are looking for an "internal clock" within the brain—an internal mechanism that is thought to be responsible for time measurement.

Many experiments in this realm indicate that while for all observers the hands of a clock turn at the same pace, different people experience time as passing more quickly or slowly (e.g., Fraisse, 1963; James, 1890/1998; Ornstein, 1975; Wearden,

2015; Friedman & Janssen, 2010; Michon & Jackson, 2012; Hoerl, 2018; Sabariego et al., 2021). The activity level of the individual is considered to be the key factor in the subjective speed of time, rather than the value of time.

There is also an interesting angle and unchartered territory to explore in mental imagery and time, referred to as subjective time perception in imagery. The brain appears to have a second clock that operates without sensory stimulation from the outside world (Isham & Izadifar, 2023; Izadifar et al., 2022). A wide variety of cognitive experiences involve mental imagery, namely the generation and manipulation of mental images without sensory input.

In relation to understanding time perception in mental imagery, which is the main theme of this paper, there are some classic studies. According to one of them, a map's distance between two sites regulates the extent of mental travel time required (Kosslyn et al., 1978; Pylyshyn, 1973). That study suggested that, although participants acted in visual mental imagery, representations of the space and time of the actual actions were kept. Subsequently, Guillot and Collet (2005) discussed recent motor imagery studies in which action time

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during imaging was underestimated in 8 cases, overestimated in 12, and had relatively precise timings in 13.

Using a walking task and a writing task, Papaxanthis et al. (2002) compared imagined and real movements. Participants in this experiment walked for 6 m and then imagined walking for 6 m at a convenient speed. It was found that there were no significant differences in accuracy between this task and the writing task (Participants should do a writing task e.g. an address in Paris: '2 Rue de la Libération' in imagery and actual condition).

Papaxanthis et al.'s (2002) experiment confirms the results of an experiment performed by Decety et al. (1989). Participants were shown visual targets located at 5, 10, or 15 m. Following that, they were blindfolded and asked to walk to each target in reality and in imagery. In a similar manner to the findings of Papaxanthis et al., Decety and his colleagues found that the participants took almost the same time for the actual and mental performances. Over all three distances employed, the results remained constant. According to this, imagery is accurate for flat paths within a distance of 15 m. What about longer distances? At longer distances, the data are less clear.

Hanyu and Itsukushima (1995) analysed imaging time when examining the cognitive distance between a flat path and a stairway. Participants were instructed to close their eyes and imagine that they were walking from the perspective of a first-person observer. The results showed that the imagery walking times for the stairway (30.8 m) were close to real walking times, while those for the flat path (46 m) were underestimated.

Apart from distance imagery and its relation to time perception, Calmels and Fournier (2001) discovered that time accuracy is affected by the difficulty of the task. These authors studied gymnasts' motor imagery. The gymnasts' time perception of motor imagery was shorter for the performance of easier sequences and longer for more difficult ones. Other experiments have confirmed the imagery timing difference according to the difficulty of the task (Decety et al., 1989; Howard et al., 2013; Jeannerod, 1995; MacIntyre & Moran 1996; Mashat et al., 2019; Munzert et al., 2009; Rosenbaum, 2021).

Perhaps the temporal aspects of imagery can be better understood through consideration of the established awareness of other temporal systems, but so far this has not been investigated. Despite the potential role of imagery in motor and non-motor activities, researchers modeling temporal processes and their underlying neural mechanisms have shown little interest in studying the temporal aspects of imagery. An analysis of task-dependent timing errors in imagery may inform us of the significance of sensory input in precise temporal sequencing and whether timing errors occurring in imagery follow patterns envisaged by any specific model.

In investigating time perception and searching for a specific model for subjective time estimation (STE) in imagery among musicians, we performed an experiment on subjective time perception in (musical) imagery. To the best of our knowledge, STE in musical imagery has not been investigated in any detail. Most subjective time duration tasks are divided into two methodological approaches: paradigms of prospective and retrospective inquiry in reality (perception). In the prospective model, participants are clearly told in advance that they will be obliged to judge the length of an interval. Participants presumably track the passing of time actively in this process and focus on any temporal signals available. In the retrospective model, however, participants are not provided any advance notice about time decisions. After an interval has elapsed, participants are unexpectedly asked to determine its duration. Thus, in this case, participants process temporal information in a more incidental and inaccurate manner. Our experiment, which is almost analogous to a retrospective approach, aims at discovering a distinct brain pattern in the subjective interpretation of time in imagery. Furthermore, this study paves the road for proposing new and independent models of timing in the brain (timing in imagery) rather than focusing merely on timing in perception.

MATERIALS AND METHODS

Participants

Ten volunteers were recruited for the experiment. Of these, 7 were professional violinists (2 males and 5 females, age range between 20 and 38 years old, who had begun playing the violin at 7 years old. Mean age = 31.14, median age = 35, SD = 7.07). Those three were also professional violinists, but the started violin in older time of their life (around 13 years old). All the participants were professional. We tried to recruit more participants, but owing to exclusion criteria (the COVID-19 pandemic, repeated lockdowns in the city, and closure of the Institute), we were unable to do so. The participants had normal or corrected vision and had no history of neurological disease. The participants received an amount of money for their participation. The study followed ethical guidelines that were approved by the Ethical Committee of Ludwig-Maximilian University of Munich, in agreement with the Declaration of Helsinki.

Material

To obtain an overview of the participants' prior familiarity with imaging and mental rehearsal, as well as of their mental attitude to learning and performing in general, a validated musical imagery task (in the form of a questionnaire) was created to check the mental practices and imagery abilities of the participants. We asked the subjects to complete the "Vividness of Mental Imagery Questionnaire" (VMIQ; Isaac et al., 1986) to assess their ability regarding mental imagery. The VMIQ comprises 24 items that represent the internal point of view and 24 items that reflect the external point of view. The internal point of view refers to a subject's ability to imagine that he or she is doing the movement, whereas the external point of view refers to the subject's ability to imagine someone else doing it. A score of each item was required: 5 (no single image), 4 (vague and fuzzy image), 3 (moderate imagination of a movement), 2 (good imaginability of movement results), or 1 (excellent imagination of movement performance as lively as real achievement). These items covered/involved mental imagery for each of the senses, including sight, sound, taste, smell, movement, and interoceptive and exteroceptive sensations to assess imagery vividness. The VMIQ test has been included in

the appendix section of this paper. At the end of the experiment, participants were also asked to provide a written summary of their imagery experience during the experiment. In the self-report summary, most participants described their experiences during the experiments. Some of them reported that while doing the imagery task they were also hearing the musical piece, while others did not report such an experience. Finally, a mental chronometry task was built with the goal of offering a contextually significant, objective measure of imaging capacity that goes beyond self-reporting.

Stimuli and apparatus

Presentation® software (version 18.0, Neurobehavioral Systems, Inc., Berkeley, CA) was used to control the experiment and to record responses. Beep stimuli were generated from the sound by Audacity software version 2.4.2 (Audacity Team Co., Free Software, registered trademark of Dominic Mazzoni, Carnegie Mellon University, Pittsburgh, PA, www.audacityteam.org) and exported as wav files for use in Presentation®.

Procedure

Upon completion of the survey and the questionnaire, participants were asked to play a short violin piece of their choice that was of public performance standard. We recorded the time duration of their playing (actuality). Then, we asked them to play the same piece in imagery while in an MRI machine. To clarify the mental timing task, participants were asked to maintain their imagery from the beginning of the musical piece until the end. In other words, among the four aspects of visual imagery—image generation, image maintenance, image inspection, and image transformation—we intend to focus on one aspect of (visual) imagery in time (image maintenance). Image maintenance is the ability to preserve an image over time. This maintenance is important because the visual buffer keeps information only for a very short time span, and visual imagery can only be maintained with constant attention over time.

The imagery task was composed of two conditions: (i) continuous (participants played their chosen piece of music in imagery from the beginning until the end continuously); and (ii) interrupted (once participants had begun to play the piece in imagery, they were interrupted by beeps at intervals of 2, 3 and 6 s). The timing intervals (2-, 3- and 6-s beeps) were randomly distributed. The participant was required to pause while they heard the beeps and then continue playing. We considered two conditions (continuous and interrupted) in order to understand the flow of imagery more deeply. We speculated that different brain patterns might exist for constant flow and interruptions.

fMRI imagery screening task and data acquisition

Brain imaging data were obtained with a 3T MRI scannerc with a standard head coil at the university hospital of Ludwig-

Maximilian University, Munich. For BOLD signals, T2*-weighted EPI sequences were used (repetition time [TR] = 2500 ms; echo time [TE] = 30 ms; flip angle = 90°; acquisition matrix = 80 × 80; number of slices = 43; slice thickness = 3 mm; no gap between slices). In total, one run of 372 functional volumes was acquired for a participant. Structural data were acquired with a T1-weighted scan of each participant's brain anatomy (1 mm × 1 mm × 1 mm; 240 × 240 matrix; field-of view = 220 mm).

All neuroimaging data were preprocessed and analyzed using SPM12 (Statistical Parametric Mapping V12, http://www.fil.ion.ucl.ac.uk/spm). The functional scan volumes were subjected to spatial realignment to correct for head motion. In further preprocessing analysis, the mean functional image was co-registered to the anatomical image, normalized to the Montreal Neurological Institute (MNI) template provided in SPM12, and spatially smoothed to reduce noise using a Gaussian kernel of 8-mm full width at half maximum. The task was modeled as a block design. Using a two-level procedure, we applied a general linear model (GLM) using predictors convoluted with a typical hemodynamic response function. To specify first-level statistics, the two imaging conditions (continuous and interrupted) were compared with the resting-state condition (continuous condition vs. resting-state condition, and interrupted condition vs. resting-state condition). We obtained parameter estimates for each condition, and then acquired statistical parametric maps of the t-statistic resulting from linear contrasts between the experimental conditions compared with their corresponding control conditions. Then, contrast images were entered in a one-way repeated measure analysis of variance (ANOVA) for second-level analysis. For these t-tests, significant voxels initially passed a voxel-wise statistical threshold of $p \leq .001$, and a cluster-level threshold was obtained at the statistical significance level of $p < .05$.

RESULTS

Behavioral results

The primary goal of the behavioral component of the study was to examine whether there was a difference in the duration of actual and imagined performance. The durations were different for the actual and imagery conditions, and it is quite worth noting. The ANOVA results revealed a significant main effect of task [$F(4,30) = 4.03$, $p < .01$, ES = 0.15], and a post hoc Tukey HSD test showed the interrupted imagery to be significantly different from the actual task ($p < .05$), with a consistent tendency for overestimation in the two imagery conditions (continuous and interrupted; Figures 1 and 2 respectively).

Imaging results

In the analysis of the fMRI data, a widely distributed cortical network was found to be active during continuous imagery.
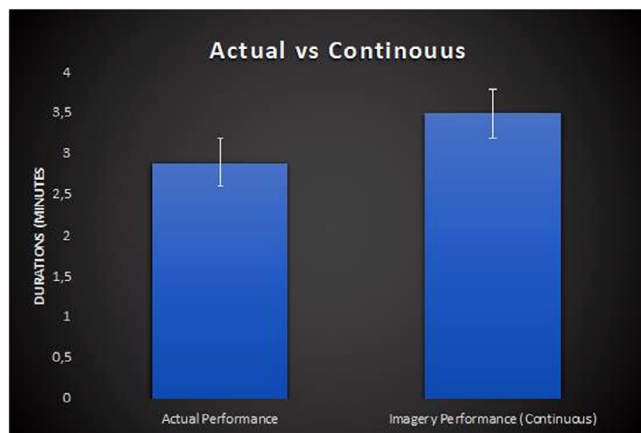
FIGURE 1 Performance duration in reality and imagery in two conditions (continuous and interrupted). The violinists were required to imagine playing a musical piece. The duration was steadily overestimated ($p < .05$) during imagery in both conditions. Participants were asked to visualize playing their favorite piece of music as accurately as possible, as if they were actually playing it in reality. Image accuracy was thus emphasized more than temporal movement characteristics. We did not inform participants that this experiment was about timing in the brain.
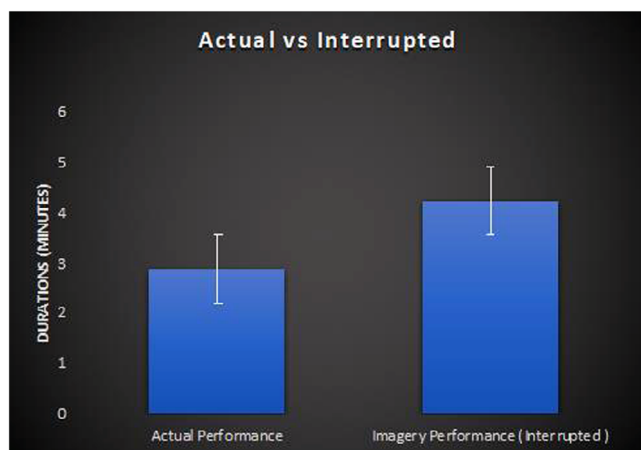

FIGURE 2 Performance duration in reality and imagery in two conditions (continuous and interrupted). The violinists were required to imagine playing a musical piece. The duration was steadily overestimated ($p < .05$) during imagery in both conditions. Participants were asked to visualize playing their favorite piece of music as accurately as possible, as if they were actually playing it in reality. Image accuracy was thus emphasized more than temporal movement characteristics. We did not inform participants that this experiment was about timing in the brain.

This network includes the right planum polar, left transverse temporal gyrus, left cerebellum exterior, and right middle temporal gyrus. In addition, activation of the right middle occipital gurus and left angular gyrus was observed (Table 1, Figure 1A). The comparison of interrupted imagery versus resting state revealed activation in the right superior frontal gyrus and right middle frontal gyrus (Table 1, Figure 1B). Moreover, there was significant activation of the left cerebellum exterior as an overlap region between the two conditions. The Venn diagram illustrates the overlap between these two comparisons

(Figure 2). We assume that the overlap region might be an important neuronal marker in maintaining imagery over time and play a vital role in creativity and timing in the brain.

DISCUSSION

Owing to the nature of this experiment, we have divided the discussion into two parts. In the first part, the temporal aspect of music imagery is addressed. In the second part, the possible roles of the different areas in the cortical processing of music imagery and their relationship to different time models of the brain are discussed.

Temporal aspect

Is the time required to execute mental imagery equal to the time required to perform in reality? Although it seems so, there is some controversy. It seems to us that our experiment is no exception. Our behavioral results of the timing tasks showed different temporal durations for the actual and imagery conditions, which were quite different from the consciously perceived time of the musical performance in reality.

However, the task difficulty may have had an effect on the temporal control of mental imagery. In other words, we assume that playing the violin is a difficult task at all levels, and this difficulty might affect the process of the exact timing in the two conditions (actual vs. imagery). Also, we should not ignore the role of emotion in performance. Another reason might lie in the fact that any change in "mental speed" throughout the entire performance in imagery relates to emotional factors among musicians. In our case, the mental imagery emotions cause an overestimation in duration.

Another possibility could be that, as the violinists have reported, they got tired during the imagery at the end, and therefore they may have speeded up their imagery task. We assume that definitive answers to these questions on the behavioral level remain open.

Furthermore, the presence of diverse timing in imagery could aid our knowledge of the fundamental mechanism of creativity, imagery, and time. That is, mental imagery is an important part of generating new ideas, and its use and application are dependent on strategic imagery and brain timing skills. In relation to future research, our findings provide some preliminary evidence of the subcomponents of the interactions between imagery, creativity, and time in distinct areas of brain science. Various cognitive functions interact to provide creative activity, alongside the highly comprehensive brain system. The brain network we observed in our experiment during musical imagery (Figure 4, Venn diagram) might be a significant starting point for enhancing creativity in time. Despite the fact that the significance of mental imagery in creativity has been widely accepted, we admit that some aspects remain unresolved. Finally, because there is no consensus on or adequate study of creativity and time, the brain bases of creativity in this realm must be further explored.

TABLE 1 Location of brain regions: comparison of the continuous condition versus resting state, and the interrupted condition versus resting state.

Brain regions	MNI coordinates			z scores	Number of voxels
	x	y	z		
Continuous vs. resting state					
R planum polar	48	−4	−4	5.70	139
L transverse temporal gyrus	−54	−19	−8	5.77	87
L cerebellum exterior	−21	46	−25	5.62	1031
R middle temporal gyrus	69	−37	2	4.93	94
R middle occipital gyrus	45	−70	20	4.57	72
L angular gyrus	−57	−61	17	4.53	72
Interrupted vs. resting state					
R superior frontal gyrus	21	68	20	7.42	32
R middle frontal gyrus	51	32	35	7.36	36
L cerebellum exterior	−33	−76	−52	6.29	45

Note: Activation of the right middle occipital gurus and left angular gyrus was observed. The comparison of interrupted imagery versus resting state revealed activation in the right superior frontal gyrus and right middle frontal gyrus. There was significant activation of the left cerebellum exterior as an overlap region between the two conditions.
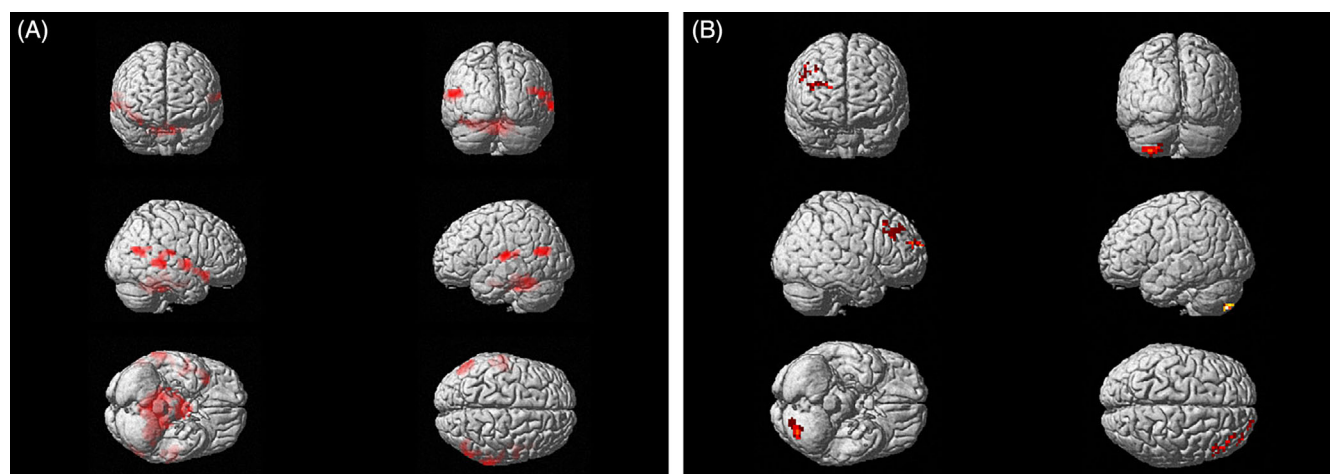

FIGURE 3 (A, B) Statistical parametric mapping of imagery in musical performance in the continuous condition. Depicted activation differences were computed with t-statistics contrasting blood-oxygen-level-dependent signals when the violinists played the piece in imagery without stops (continuous) compared with the resting state (Figure 1A) and when interrupted compared with the resting state (Figure 1B). Activations were cluster-level-corrected with p (familywise error; FWE) < .05. The x, y, and z coordinates were normalized using a standard brain from the Montreal Neurological Institute and displayed as per radiological convention.

Cortical processing

When violinists played music in imagery in the continuous condition, we saw that brain regions including the right planum temporal, left transverse temporal gyrus, left cerebellum exterior, right middle temporal gyrus, middle occipital gyrus and angular gyrus were activated (Figure 3A,B). In the interrupted condition, regions including the right superior frontal gyrus, right middle frontal and left cerebellum exterior were active. The overlapregion in the two conditions, the left cerebellum exterior, needs more attention. This is consistent with the outcomes of other studies on imagery and actual performance (Anderson, 1982; Jäncke et al., 2000; Meister et al., 2004).

One might ask why we implemented the imagery task in two conditions (continuous and interrupted). First, we wanted to know whether interrupting the flow of imagery might have an effect on timing. Second, we speculated that the imaging data in our experiment might show very different neural patterns for the interrupted imagery and continuous imagery. We thought that the brain would use a completely different mechanism in handling an interrupted situation.

Because the continuous and the interrupted imagery in our experiment shared the same semantic content, a common neural machinery, if it exists, should be related to such a commonality. Cerebellum activity was seen in our task, and we wonder whether it might be responsible for the coordination and temporal integration of the specific task. Indeed, the cerebellum in the left
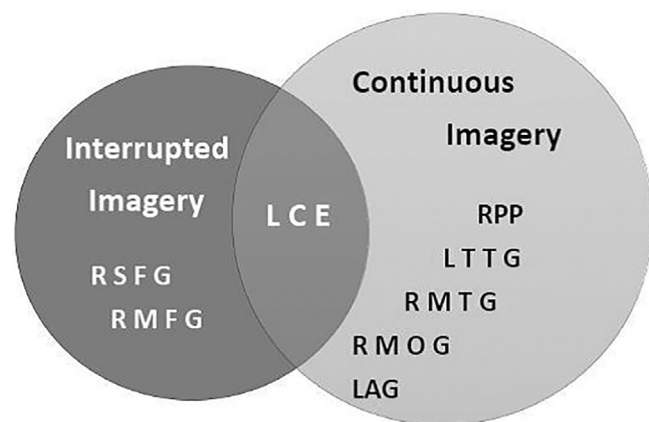
FIGURE 4 Venn diagrams illustrating the overlap between the continuous condition versus resting state and interrupted versus resting. Circle size is proportional to the size of the networks identified. Abbreviations indicate the brain regions where activities were found: RSFG, right superior frontal gyrus; RMFG, right middle frontal gyrus; LCE, left cerebellum exterior; RPP, right planum polar; LTTG, left transverse temporal gyrus; RMTG, right middle temporal gyrus; RMOG, right middle occipital gyrus; LAG, left angular gyrus.

hemisphere was activated for both continuous and interrupted imagery conditions, as shown in the Venn diagram (Figure 4).

Is there any other evidence supporting the above speculation? The cerebellum was shown to be critical in an examination of cortical correlates of motor imagery (Grealy & Shearer 2008; Lotze et al., 1999). Motor/rhythm synchronization (Schubotz et al., 2000) and balance (Ramnani et al., 2001) are two other activities in which cerebellar involvement has been demonstrated. The findings in this experiment also align with dedicated models of timing such as the cerebellar timing hypothesis (Ivry et al., 2002), which assigns a 'specialized clock' for tasks. The cerebellar timing hypothesis is based on the premise that the cerebellum is capable of being understood special and available when a given task requires accurate timing.

However, it seems that the brain is crammed with different clocks that depend on the task being undertaken, and these different clocks function for the crucial aspect of temporal integration. Other neuronal regions that may act as dedicated timing mechanisms have been the target of related claims (Meck, 2005). The basal ganglia (Harrington, Haaland, & Hermanowicz, 1998; Rao et al., 2001), supplementary motor area (Coull et al., 2004; Macar et al., 2006), and prefrontal cortex, especially in the right hemisphere (Harrington, Haaland, & Knight, 1998; Lewis & Miall, 2006), have been noted. To conclude, it was speculated that interrupted imagery and continuous imagery might reveal very different neural patterns in our experiment. An interrupted situation triggers a completely different mechanism in the brain alongside the different time perception pattern that we observed.

The experiment presented here is not intended to be conclusive of all studies on temporal matters. Rather, our study serves as an example of various approaches to the theoretical basis of temporal matters in brain science. The bottom line in all of these cases is that there are many extant ways to theorize

about temporal matters and brain timing models. The body of literature on this topic has expanded in recent years. However, much will and should be done to advance our knowledge of temporal aspects and their role in understanding the brain.

CONFLICT OF INTEREST STATEMENT
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

ETHICS STATEMENT
The study followed ethical guidelines that were approved by the Ethical Committee of Ludwig-Maximilian University of Munich, in agreement with the Declaration of Helsinki.

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APPENDIX I

VVIQ Test:

Think of some relative or friend whom you frequently see (but who is not with you at present), and consider carefully the picture that comes before your mind's eye. Then rate the following items:

Q1 The exact contour of face, head, shoulders, and body.

- ○ No image at all (only "knowing" that you are thinking of the object)
- ○ Vague, and dim
- ○ Moderately clear and vivid
- ○ Clear and reasonably vivid
- ○ Perfectly clear and as vivid as normal vision

Q2 Characteristic poses of head, attitudes of body, etc.

- ○ No image at all (only "knowing" that you are thinking of the object)
- ○ Vague, and dim
- ○ Moderately clear and vivid
- ○ Clear and reasonably vivid
- ○ Perfectly clear and as vivid as normal vision

Q3 The precise carriage, length of step, etc., in walking.

- ○ No image at all (only "knowing" that you are thinking of the object)
- ○ Vague, and dim
- ○ Moderately clear and vivid
- ○ Clear and reasonably vivid
- ○ Perfectly clear and as vivid as normal vision

Q4 The different colors worn in some familiar clothes.

- ○ No image at all (only "knowing" that you are thinking of the object)
- ○ Vague, and dim
- ○ Moderately clear and vivid
- ○ Clear and reasonably vivid
- ○ Perfectly clear and as vivid as normal vision

Visualize a rising sun. Consider carefully the picture that comes before your mind's eye. Then rate the following items.

Q5 **The sun is rising above the horizon into a hazy sky.**

- ( ) No image at all (only "knowing" that you are thinking of the object)
- ( ) Vague, and dim
- ( ) Moderately clear and vivid
- ( ) Clear and reasonably vivid
- ( ) Perfectly clear and as vivid as normal vision

Q6 **The sky clears and surrounds the sun with blueness.**

- ( ) No image at all (only "knowing" that you are thinking of the object)
- ( ) Vague, and dim
- ( ) Moderately clear and vivid
- ( ) Clear and reasonably vivid
- ( ) Perfectly clear and as vivid as normal vision

Q7 **Clouds. A storm blows up, with flashes of lightning.**

- ( ) No image at all (only "knowing" that you are thinking of the object)
- ( ) Vague, and dim
- ( ) Moderately clear and vivid
- ( ) Clear and reasonably vivid
- ( ) Perfectly clear and as vivid as normal vision

Q8 **A rainbow appears.**

- ( ) No image at all (only "knowing" that you are thinking of the object)
- ( ) Vague, and dim
- ( ) Moderately clear and vivid
- ( ) Clear and reasonably vivid
- ( ) Perfectly clear and as vivid as normal vision

Think of the front of a shop to which you often go. Consider the picture that comes before your mind's eye. Then rate the following items.

Q9   **The overall appearance of the shop from the opposite side of the road.**

- ◯ No image at all (only "knowing" that you are thinking of the object)
- ◯ Vague, and dim
- ◯ Moderately clear and vivid
- ◯ Clear and reasonably vivid
- ◯ Perfectly clear and as vivid as normal vision

Q10   **A window display including colors, shapes, and details of individual items for sale.**

- ◯ No image at all (only "knowing" that you are thinking of the object)
- ◯ Vague, and dim
- ◯ Moderately clear and vivid
- ◯ Clear and reasonably vivid
- ◯ Perfectly clear and as vivid as normal vision

Q11   **You are near the entrance. The color, shape, and details of the door.**

- ◯ No image at all (only "knowing" that you are thinking of the object)
- ◯ Vague, and dim
- ◯ Moderately clear and vivid
- ◯ Clear and reasonably vivid
- ◯ Perfectly clear and as vivid as normal vision

Q12   **You enter the shop and go to the counter. The counter assistant serves you. Money changes hands.**

- ◯ No image at all (only "knowing" that you are thinking of the object)
- ◯ Vague, and dim
- ◯ Moderately clear and vivid
- ◯ Clear and reasonably vivid
- ◯ Perfectly clear and as vivid as normal vision

Finally, think of a country scene which involves trees, mountains and a lake. Consider the picture that comes before your mind's eye. Then rate the following items.

Q13 **The contours of the landscape.**

- ◯ No image at all (only "knowing" that you are thinking of the object)
- ◯ Vague, and dim
- ◯ Moderately clear and vivid
- ◯ Clear and reasonably vivid
- ◯ Perfectly clear and as vivid as normal vision

Q14 **The color and shape of the trees.**

- ◯ No image at all (only "knowing" that you are thinking of the object)
- ◯ Vague, and dim
- ◯ Moderately clear and vivid
- ◯ Clear and reasonably vivid
- ◯ Perfectly clear and as vivid as normal vision

Q15 **The color and shape of the lake.**

- ◯ No image at all (only "knowing" that you are thinking of the object)
- ◯ Vague, and dim
- ◯ Moderately clear and vivid
- ◯ Clear and reasonably vivid
- ◯ Perfectly clear and as vivid as normal vision

Q16 **A strong wind blows on the trees and on the lake, causing waves.**

- ◯ No image at all (only "knowing" that you are thinking of the object)
- ◯ Vague, and dim
- ◯ Moderately clear and vivid
- ◯ Clear and reasonably vivid
- ◯ Perfectly clear and as vivid as normal vision