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Research article

Elderly adults show higher ventral striatal activation in response to motor performance related rewards than young adults

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ABSTRACT

Feedback on motor performance activates the striatum and boosting ventral striatum activation with rewarding feedback during motor training supports the consolidation of the learned skill. Aging is associated with changes of the reward system, including striatal and extrastriatal loss of dopamine receptors. How these changes interact with the blood oxygenation level dependent (BOLD) response is, however, not yet fully understood. While it is known that reward prediction and reward-based decision-making differ between young and elderly healthy adults, the influence of age on the processing of rewarding feedback on motor performance have not been investigated so far.

Nineteen young (26.42 ± 2.84 years) and 18 elderly (65.39 ± 6.40 years) healthy adults performed an arc-tracking task including performance feedback linked to a monetary reward after half of the trials, while undergoing functional magnetic resonance imaging (fMRI). The BOLD effect was compared in three predefined regions of interest: Ventral and dorsal striatum plus primary motor cortex.

Our study demonstrates differences in the processing of motor performance related reward between young and elderly healthy adults. While both groups earned similar amounts of money linked to their own performance, the ventral striatal response to the rewarding feedback was higher in the older group. Deficient prediction about the rewarding feedback, a higher motivational status or compensation for a reduced number of dopamine receptors in the elderly might be possible explanations. How this interacts with the reward-induced improvement of motor skill consolidation, as observed in young subjects, has to be clarified.

1. Introduction

The receipt of a reward is associated with increased striatum activation [11,21]. More specifically, intrinsic reward (e.g., performance feedback) leads to increased activation of the ventral striatum (vStr), which even further increases when feedback is linked to an extrinsic reward (e.g., money). Notably, in a rewarded task the neural activity in the striatum correlates with striatal dopamine (DA) release [16]. Moreover, studies performed with healthy young individuals demonstrated that training under a rewarded condition positively influences motor skill learning when compared with a control condition [21]. However, it must be considered that the human reward system changes with age, including striatal and extrastriatal loss of DA-receptors [9,13]. Previous research has revealed differences in reward prediction [5,17] and reward-based decision-making [4] between young and elderly healthy adults. These studies found a decreased striatal response to reward, reward prediction errors, and reward anticipation in elderly. Interestingly, when using tasks which did not require learning, striatal activity was not different [15]. Yet, it is unclear how these changes over the lifespan affect reward processing that is related to the performance in a motor task. Considering the loss of DA receptors, adequate feedback-related motor learning might actually require an upregulation of the neural response to rewarding feedback in an aging population. A potentially reduced activation, on the other hand, could be an implication for impaired motor performance, as it has been observed in some cognitive and motor tasks [20], and thereby negatively affect the motor system's ability to adapt to changing situations.

We therefore asked whether processing of motor performance

Abbreviations: BOLD, blood oxygenation level dependent; CHF, Swiss Francs; DA, dopamine; dStr, dorsal striatum; fMRI, functional magnetic resonance imaging; IMI, intrinsic motivation inventory; M1, primary motor cortex; ROI, region of interest; vStr, ventral striatum

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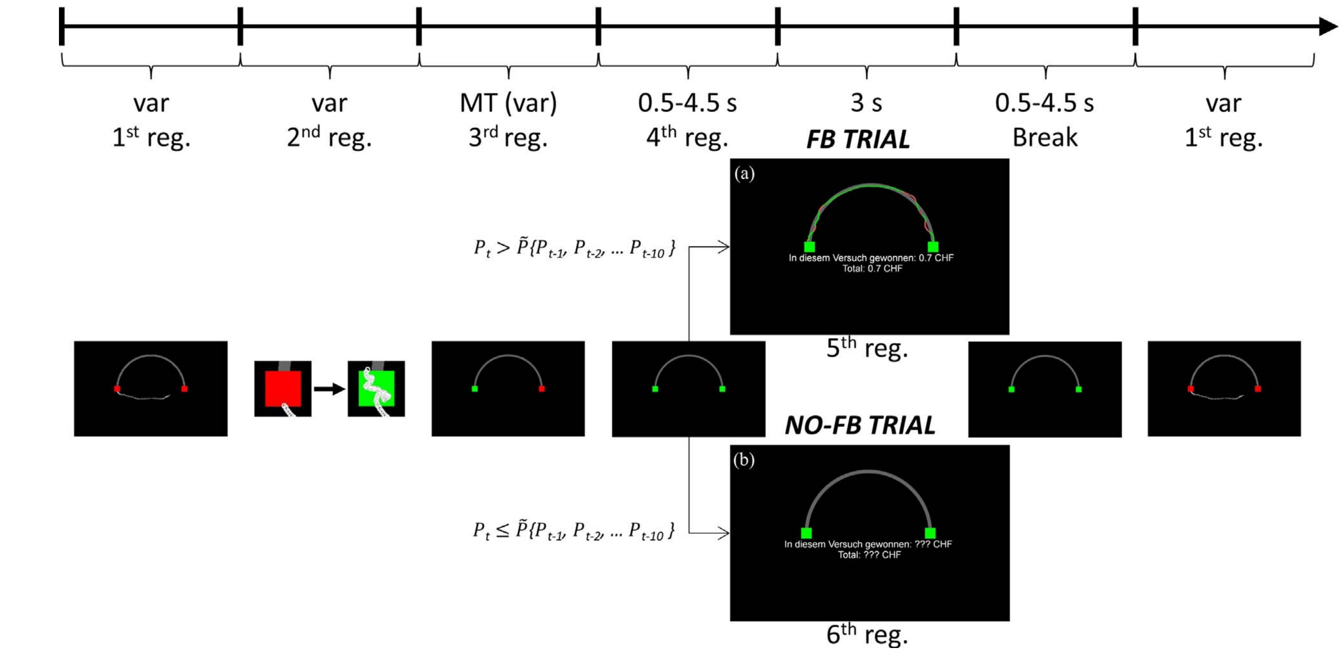

Fig. 1. Trial sequence. After placing the cursor in the start box, the box eventually turned green ("ok-to-go" signal) and subjects were free to start the movement whenever ready. The placing of the cursor in the start box, as well as the period from "ok-to-go" to the actual start of the movement were self-paced and hence of variable length (var), as was the movement time (MT) to steer the cursor through the semicircular channel. As soon as the target box was reached, the screen froze. (a) Feedback screen presented after feedback trials (FB TRIAL), that is, if performance of the current trial (P_t) was better than the median ($\tilde{P}$) over the previous ten trials $\{P_{t-1}, P_{t-2}, \ldots P_{t-10}\}$. The money gained in the current trial (in German: "In diesem Versuch gewonnen: 0.7 CHF") and the total money won ("Total: 0.7 CHF"), both in Swiss Francs (CHF), were presented together with the trajectory travelled by the cursor. (b) No-feedback trial. If P_t was not better than $\tilde{P}$, subjects were shown a neutral visual control stimulus (NO-FB TRIAL). Note that the amount of money gained in the current trial as well as the total money were replaced by three question marks and the trajectory was omitted. Either way, the next trial began after a delay period (break). Notably, onsets and durations of six of the seven regressors (reg.) are marked on the time axis (TOP). The 7th regressor was a parametric modulation of the feedback regressor by the magnitude of the monetary reward. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

related reward differs between young and elderly healthy adults. For this purpose, we had 20 young and 20 elderly healthy subjects perform a motor skill task while undergoing functional magnetic resonance imaging (fMRI). An arc-tracking task was used, and a performance feedback including a monetary reward linked to performance was given after half of the trials. The striatal response to the rewarding feedback was then compared between the two groups.

2. Methods

2.1. Participants

Twenty young (22–35 years of age) and 20 elderly (over 55 years of age) healthy native German-speaking adults participated in this study which was approved by the competent ethics committee (EKNZ BASEC 2016-00079). All subjects gave written informed consent according to the Declaration of Helsinki. Exclusion criteria included psychiatric disorders, intake of central nervous drugs (e.g. antidepressants), and pregnancy (tested for each woman of child-bearing age). Moreover, an MRI-safety-questionnaire was used to check for any MRI contra-indications. All subjects were naïve to the task, received identical instructions and underwent identical study procedure. They received financial compensation depending on their performance during the motor task.

2.2. Procedure

The study required one measurement session at the cereneo, center for neurology and rehabilitation in Vitznau, Switzerland. After the informed consent procedure, subjects were asked to fill in a depression- (Beck Depression Inventory, BDI II, Beck et al. [1]) and a handedness-questionnaire (Edinburgh Handedness, Williams [22]). Additionally, cognitive screening was performed using the Montreal Cognitive Assessment (MoCA, Nasreddine et al. [12]). Finally, after completion of the fMRI task, subjects were asked to fill in a motivation assessment (Intrinsic Motivation Inventory, IMI, http://selfdeterminationtheory.org/intrinsic-motivation-inventory).

2.3. Motor task

To examine the processing of motor performance related reward, both groups performed a modified arc-pointing task [18,21], which allowed to gain money linked to motor performance while undergoing fMRI. A spherical reflective marker was attached to the index finger of the dominant hand. This marker was continuously tracked using a MRI-compatible motion capture system (Oqus MRI, Qualysis AB, Gothenburg, Sweden) and was synchronized with a representative cursor on the screen by a computer program written in "Presentation 16.3" software (Neurobehavioral Systems, Inc., Albany, NY, USA). Hence, by moving the wrist of the dominant hand subjects could steer a cursor through a semicircular channel in clockwise direction and in their preferred movement speed from a defined start- to an end-box while trying not to leave the channel. For a more detailed description of the setup see Widmer et al. [21].

The assessment started with a short familiarization period of 20 trials. This was used to adapt the size of the channel in order to make sure that all participants are able to perform the rewarded task at a similar performance level and, since monetary rewards were linked to performance, to balance out amounts of money gained in the two groups. Difficulty was adjusted by changing the channel width, which was set 12 pixels (≈0.12° visual angle) smaller after trials with more than 70% of the trajectory inside the channel, and 12 pixels wider when less than 30% of the trajectory were within the channel. Minimal channel size was 12 pixels.

Thereafter, each subject performed four blocks of 25 trials with a fixed channel size (as evaluated during the familiarization period)