This sounds good! Hurdling and tap-dancing re-afferences are processed differently in the brain

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Introduction

Audible effects of our own actions…

- can be the intended goal of an action (**g**oal-related **a**ction **s**ounds, GAS; e.g. language, music, tap dancing).
- can be an incidental by-product of an action (**b**y-product **a**ction **s**ounds, BAS; e.g. walking, hurdling).

Importance of action sounds/auditory feedback for action execution

- Omitted/altered auditory feedback interferes with action execution in GAS[1,3].
- Omitted/altered auditory feedback has no influence on action execution in BAS[2].

Prediction of self-generated movement sounds

- Efference copy in the auditory cortex is responsible for the suppression of action-related auditory feedback[4] .
- Sensory attenuation is due to predictability of self-generated action sounds[5]
- Unexpected sound omission evokes a surprise response in form of a mismatch negativity[6]

Questions

1. Has the omission of action sounds diverging influences on the action performance evaluation and neural processing of GAS and BAS actions?
2. Is predictive information about action sounds provided whenever the sound is omitted in GAS?

Hypotheses

Behavioral

1. Rating scores for mute trials are reduced, especially in GAS compared to BAS

Functional

2. A1 is attenuated in GAS compared to BAS
3. Auditory cortices are deactivated for mute trials compared to trials with sound
4. Supplementary motor area (SMA) provides predictive information whenever the sound is missing in GAS, restoring the behavioral rating scores
5. SMA activity only correlates with rating scores when the predictive model is retrievable from an intact visual input

Methods

Sample

- 12 participants (8 females, 4 males)
- 19 – 28 years old

Stimuli

- Point light videos of hurdling (BAS) and tap dancing (GAS, mean duration 5 s)
- Fade-in and fade-out (1 s)
- Videos with
  - Intact picture and sound
  - Intact picture and omitted sound
  - Scrambled picture and omitted sound

Task and conditions

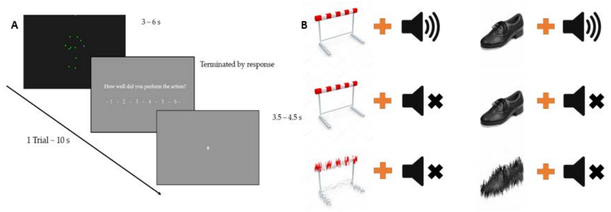


Fig. 1. Task and conditions. (A) A trial consists of a video (3 – 6 s in length), followed by the video rating question ("How well did you perform the action?" in German with rating scores on a 6-point Likert Scale), and a fixation cross (3.5 – 4.5 s in length). The total duration of one trial is approximately 10 s. (B) Experimental conditions consisted of trials with sound, without sound, and without sound and scrambled picture for both hurdling (BAS) and tap dancing (GAS).

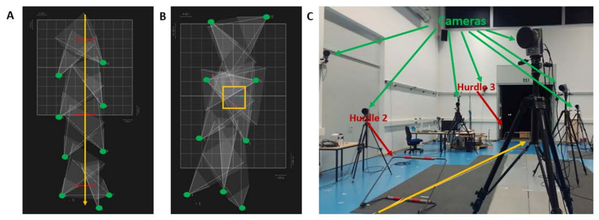
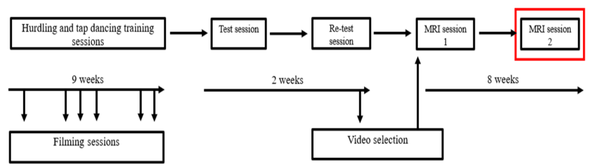


Fig. 2. Camera positions and set-up during the point light recordings. (A) Camera positions during hurdling from a top view perspective. Green dots represent the cameras, red lines the hurdles, and the yellow arrow the hurdling track. (B) Camera positions during tap dancing from a top view perspective. The yellow square the area in which the tap dancer performed the sequence (C) Set-up during the recording of hurdling. The yellow arrow indicates the hurdling track.

Procedure



fMRI contrasts

- activations time-locked to the video onset
- First-level contrasts "condition > rest"
- Second-level flexible factorial ANOVA
- False discovery rate (FDR) corrected t-maps, p < .001, k = 20

Results

Behavioural

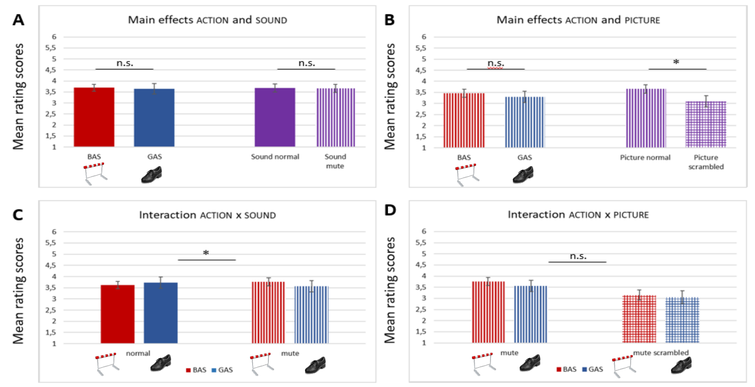


Fig. 3. Behavioral rating score results. Mean rating scores for the evaluation of the quality of the action performance presented in the observed videos, obtained during the MRI sessions. Rating scores could range from 1 to 6 (1 representing a low, 6 a high rating of quality). Error bars show standard errors. BAS conditions are represented in red, GAS conditions in blue. Vertical stripes represent the scores for *mute* conditions, whereas columns with both vertical and horizontal stripes represent the *mute* conditions with scrambled picture. (A) Main effects for the first 2 x 2 ANOVA, including the factors ACTION and SOUND. (B) Main effects for the second 2 x 2 ANOVA, including the factors ACTION and PICTURE. (C) Interaction effect for the first 2 x 2 ANOVA, including the factors ACTION and SOUND. (D) Interaction effect for the first 2 x 2 ANOVA, including the factors ACTION and PICTURE.

fMRI

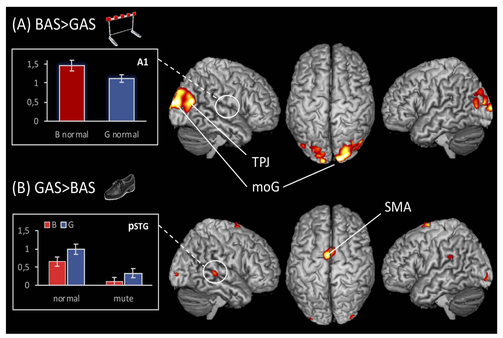


Fig. 4. Main effects of ACTION for the normal and mute conditions. (A) FDR-corrected t-maps ($p < .001$) for the BAS>GAS contrast and A1 beta values for BAS (in red) and GAS (in blue) conditions with sound. (B) FDR-corrected t-maps ($p < .001$) for the GAS>BAS contrast and pSTG beta values for BAS (in red) and GAS (in blue) conditions with and without sound.

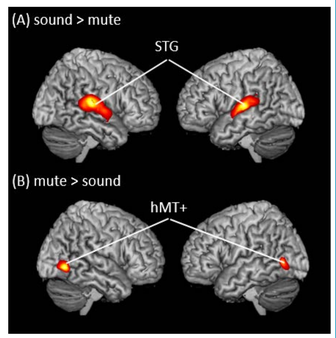


Fig. 5. Main effects of SOUND (A) FDR-corrected t-maps ($p < .001$) for the sound>mute contrast. (B) FDR-corrected t-maps ($p < .001$) for the mute>sound contrast.

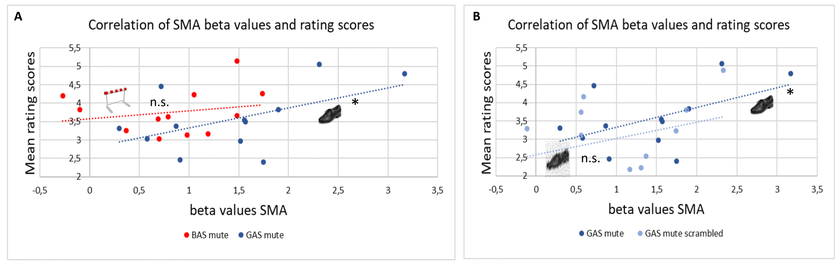


Fig. 6. Correlation of SMA beta values and behavioral rating scores. (A) Correlation between the behavioural rating scores and beta values extracted from SMA for the mute BAS (in red) and mute GAS (in blue) conditions. (B) Correlation between the behavioural rating scores and beta values extracted from SMA for the mute GAS (in blue) and mute scrambled GAS (in light blue) conditions.

Discussion

- Rating scores in the mute conditions are only reduced for GAS, but increase slightly in BAS
  - Auditory feedback is necessary for perceiving an action as well performed in GAS actions, but is an error detector in BAS actions
- A1 is attenuated in GAS compared to BAS on the level of beta values
  - Subtle attenuation effect due to more pronounced prediction in GAS vs. BAS
- Auditory cortices are deactivated in the mute conditions, with hMT+ being active instead
  - Shifted focus on biological motion
- SMA beta values correlate positively with rating scores for mute GAS, but not for mute BAS
  - SMA provides predictive input whenever actual acoustic input is missing
  - Predictive input guarantees a more positive evaluation of action performance
- SMA beta values do not correlate with rating scores for mute scrambled GAS
  - Predictive input is only retrievable from an intact visual input

Future Plans

- Influence of altered auditory feedback on BAS and GAS actions
  - Delayed action sounds
- Difference between action perception and action execution
  - Perception of action sounds without recollection of the execution of the corresponding action
  - Gender, weight and height matched control subjects

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