SHORT AND SWEET

Training synaesthesia

Nicolas Rothen¶, Andrea-Laura Wantz, Beat Meier
Department of Psychology and Center for Cognition, Learning, and Memory, University of Bern,
Muesmattstrasse 45, CH-3012 Bern, Switzerland; e-mail: nicolas.rothen@gmail.com
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Abstract. Synaesthetic inducers such as graphemes are typically cultural artifacts. Thus, a learning component seems evident in synaesthesia (Simner et al, 2009 *Brain* **132** 57 – 64). Normally, synaesthetes report to have their experiences since they can remember. Nevertheless, a recent training study suggests that synaesthesia can be mimicked in non-synaesthetes. To date, the role of learning during the development of synaesthesia is still debated. It is not clear whether synaesthesia can be learned or trained at all. To address this question, we compared a non-adaptive and an adaptive training for their effectiveness. We assessed their impact on two types of priming tasks, before and after the training. We found stronger priming in the adaptive training group suggesting that adaptive training is more efficient to mimic synaesthesia.

Grapheme-colour-synaesthesia denotes the phenomenon that graphemes involuntarily evoke sensations of colour. Automaticity of these sensations is conventionally demonstrated with synaesthetic Stroop tasks in which coloured graphemes are presented and participants have to name the colour of each grapheme. Some graphemes are in a colour congruent to the synaesthetic experience and some are incongruent. Many studies have demonstrated that synaesthetes are slower in the incongruent compared to the congruent condition (eg Dixon et al 2004). These results indicate that this type of task may be used as a diagnostic marker to identify synaesthetes (eg Odgaard et al 1999). However, recently we have demonstrated that also non-synaesthetes which were trained with letter-colour associations showed a 'synaesthetic' Stroop effect (Meier and Rothen 2009). The present study was designed to replicate and extend these findings. Forty non-synaesthete participants (twenty-three female, $M = 22$ years, SD $= 2.3$ years) were trained with either the previously used non-adaptive or a new, adaptive, digit-colour training. Pre-training to post-training changes were tested with a digit-colour priming task and a colour-digit priming task. The experimental procedure was carried out according to the Declaration of Helsinki.

First, participants were trained on digit-colour associations. In the non-adaptive training, twenty participants were presented with one of four differently coloured digits on a computer screen. They were instructed to press one key if the stimulus matched one of four predefined associations (3 red, 4 green, 5 yellow, 6 blue) and to press another key if it did not, as quickly and accurately as possible. Each training session consisted of 480 trials and required an equal number of 'match' and 'non-match' responses. In the adaptive training, another twenty participants learned the same digit-colour mapping, but they had to press a key that corresponded to a particular colour. Colour-to-key mapping changed on a trial-by-trial basis and was indicated below the digit on the screen as illustrated in figure 1. After feedback on response accuracy, participants were presented with the same digit in the correct colour hue, but with altered luminance. They had to judge whether the colour on the screen was brighter or darker than the to-be-learned colour. Adjustment of luminance on each trial followed an implemented staircase procedure depending on the previous response accuracy. In each session 248 trials were

¶ Now at School of Psychology and Sackler Center for Consciousness Science, University of Sussex; e-mail: nicolas.rothen@gmail.com. All correspondence should be sent to this address.
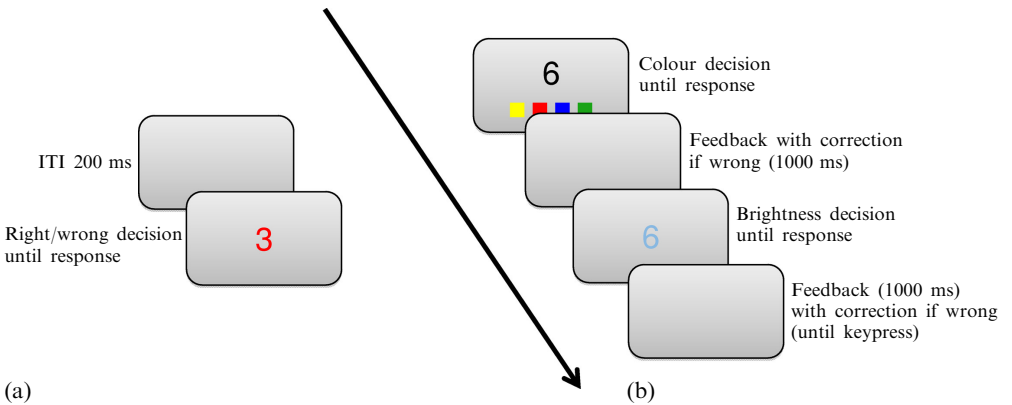
Figure 1. [In colour online, see http://dx.doi.org/10.1068/p6984] Exemplary depiction of (a) non-adaptive trial and (b) adaptive trial.

presented. Both trainings were administered on 10 consecutive days. Accuracy was high from the beginning; across all sessions mean accuracy was 0.96 (SD = 0.03) in both trainings. For the adaptive training, mean response times for the digit–colour associations were 806 ms on day 1 and dropped to 514 ms on day 10. Response time data were modelled using a power function which explained 96.5% of the variance. For the non-adaptive training, response times were 1306 ms on day 1 and dropped to 683 ms on day 10. A power function explained 90.9% of the variance.

Before and after training, participants were engaged in two priming tasks, which were counterbalanced within the testing sessions. For the digit–colour priming task, the digits 3, 4, 5, 6—and accordingly the coloured-squares red, green, yellow, blue—were used as stimuli. Each trial consisted of 5 slides, each presented for 500 ms: fixation, digit-prime, inter-stimulus interval, target-colour, and inter-trial interval. The task consisted of congruent and incongruent trials (192 trials each) which were presented in random order. Participants had to make colour decisions on the target-colour. Each of the colours was mapped to one specific finger-response. The colour-digit priming task procedure was identical except that the colours were used as primes and the digits as targets, and hence participants had to make digit decisions (cf Gebuis et al 2009). Mean reaction-time differences between congruent and incongruent trials are presented in figure 2. A mixed three-way analysis of variance with the between-subjects factor type of training (non-adaptive versus adaptive) and the within-subjects factors session (pre-training versus post-training) and task (colour-decision versus digit-decision) revealed significant main effects of session and task ($Fs_{1,38} \geqslant 6.16$, $ps \leqslant 0.018$) and the session × training interaction was suggestive ($Fs_{1,38} = 2.73$, $p = 0.107$). No other effect was significant (all $Fs < 2.09$). Due to the theoretical and practical interest, we further conducted
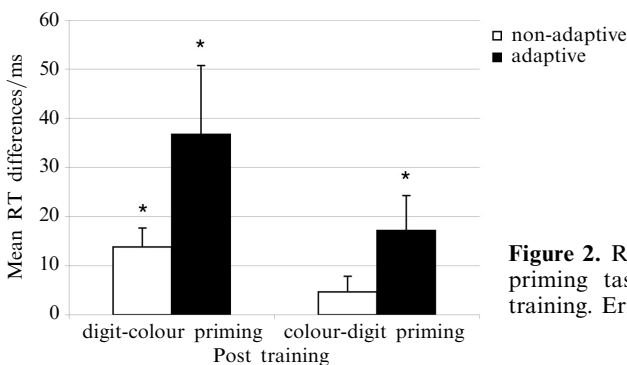

Figure 2. Reaction time (RT) differences of the priming tasks for non-adaptive and adaptive training. Error bars represent standard errors.

one-sample t-tests against 0 on post-training reaction-time differences. They revealed a significant digit-colour priming effect for both types of training and a significant colour-digit priming effect for adaptive training only (ts$_{19}$ > 2.40, ps < 0.05).

The present study suggests that adaptive training is more effective than non-adaptive training. We replicated the findings of our previous study. Due to digit-colour association training, colour associations can be automatically triggered by presenting a digit printed in black (Meier and Rothen 2009). These findings were extended, as for the adaptive training digit associations were also automatically triggered by presenting a colour. This is probably because, unlike during the non-adaptive training, in the adaptive training only 'matching' digit-colour associations have been presented. Moreover, due to the staircase procedure, the adaptive training developed associations to highly specified colours.

However, our participants did not report synaesthetic experiences after the training. This is in line with our previous study and with the results of a study in which a person extensively trained on digit-colour associations by using colour-coded cross-stitch patterns showed similar behavioural results, but no evidence for synaesthetic experiences on a neurophysiological level (Elias et al 2003). Nevertheless, future research using more extensive adapting training must reveal the boundaries of training synaesthetic experiences.

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