

One Link to Link Them All

Participant-visible method context. Results, discussion, captions, and the target figure are excluded.

Required Sample Size and Preregistration The sample size was determined based on a priori power calculation using G*Power (Faul et al., 2007). To detect an effect of $d_z = .40$ (Brysbaert, 2019) with a power of $1 - \beta = .80$ and $\alpha = .05$, $N = 71$ participants were needed. The study design and analyses plan for Experiment 1a and Experiment 1b were preregistered on the Open Science Foundation (OSF) using the AsPredicted.com template (<https://doi.org/10.17605/OSF.IO/FC5U3> for Experiment 1a and <https://doi.org/10.17605/OSF.IO/TCRM5> for Experiment 1b).

Participants In Experiment 1a, $N = 71$ participants were recruited (Mage = 21.76 years). The experiment was an online study, built on PsychoPy (v2021.2.3; Peirce et al., 2019), and was hosted on Pavlovia (<https://pavlovia.org/>) for online data collection and lasted for 20 min. Participants were German students of FSU Jena and other participants in the age range of 18–35 years who were recruited through word of mouth. Among the participants, those who were students of FSU Jena were compensated with partial course credits. For Experiment 1b, $N = 71$ participants were also recruited (Mage = 21.14 years); however, this time the participants were recruited via Prolific and were German native speakers between the age group of 18–35 years. The participants were compensated £ 3.50 according to the norms of Prolific. Only German native speakers were recruited since the stimulus pairs used in both Experiment 1a and Experiment 1b had a German word as S2. Informed consent was given by the participant at the start of study by pressing “j” upon reading the form displaying the details of the study, the type of data collected, compensation amount, and if there are any known risks in participating in this study. Ethical approval was not required for this study as we did not convey any misleading or suggestive information (this is in accordance with the ethical standards at the Institute of Psychology of FSU Jena).

Material and Procedure The participants were instructed to only use their laptop. This study consisted of three phases. Before each phase, the instructions were displayed in white font on a black screen. In the first phase, participants were made to learn a stimulus–stimulus association wherein the visual S2 always followed a particular auditory S1 (100% contingency). Two S1–S2 pairs were introduced in Phase 1 of the study. The

participants were asked to read the S2 aloud and informed that the responses would be recorded by the microphone. To make this more convincing, prior to Phase 1, participants also read a short question that tested the microphone, and few reminders were also provided to read the word aloud. However, no microphone response was recorded, nor was there any access to their microphones. We used this mock setup to ensure that the participants paid attention to the word pairs during Phase 1 (this was revealed to participants when they were debriefed at the end of the study). The stimuli were chosen to be tailored for German participants. As S1, the pseudowords were chosen from a list of existing pseudowords (Simone et al., 2020) that were standardized and checked for being phonotactically legal with German. Mank and dels were the selected pseudowords (S1) that were recorded by a female German native speaker. As S2, Haus (house) and Wald (forest) were selected as the German words. The screen was black, and the words were presented in the Arial font with height 0.04 (units of PsychoPy). In Experiment 1a, to add a layer of distinction between the audiovisual displays and the pairs, the words were displayed in color: Haus was shown in blue, and Wald in yellow. The color was irrelevant to the task or the study design and was not mentioned in the instructions. However, since this did not serve any purpose, in Experiment 1b, the words were displayed in white against a black background. In Experiment 1a, all participants observed mank followed by Haus and dels followed by Wald, and this was not counterbalanced across participants. To eliminate any confound of a stimulus pair favoring response transfer, we counterbalanced the stimulus pairs in Experiment 1b such that approximately half of the participants ($N = 38$) learnt the pair of mank (S1) – Haus (S2) and dels (S1) – Wald (S2)

and the rest of the participants ($N = 33$) learnt the pair of mank (S1) – Wald (S2) and dels (S1) – Haus (S2). In total, Phase 1 consisted of 80 trials (40 occurrences of each pair). The association between the pseudoword and German word was built using a 100% contingency. A given trial started with a row of fixation crosses displayed for 600 ms followed by a blank screen for 200 ms and an auditory presentation of pseudowords for 800 ms followed by the visual presentation of the German word for 800 ms (see Figure 1). To establish a S2-R contingency, a forced choice number identification task was used in Phase 2. Participants had a short attention check to see if they remembered the instructions accurately. After the attention check, there was a short practice block consisting of

eight trials after which Phase 2 began. Participants saw the number 4 or 8 that appeared in the middle of the screen and responded by pressing the corresponding number key on the keyboard. The S2 (German visual word) was predictive of the number keypress with a 90% contingency. In Experiment 1a, 90% of the time, Haus was followed by the number 8 and Wald was followed by the number 4 for all the participants. In Experiment 1b, stimulus–response assignment in Phase 2 was also counterbalanced: For half of the participants ($N = 35$), Haus was mostly predictive of the number (thus response key) 8 and Wald was mostly predictive of 4, both with a 90% contingency. The remaining participants ($N = 36$) observed a 90% contingency of Haus followed by the number 4 and Wald followed by the number 8. The trials where the contingent number was shown are referred to as valid trials, and the trials where the noncontingent number appeared are referred to as invalid trials. Phase 2 consisted of 100 trials (90 valid trials and 10 invalid trials). The trial sequence in both the experiments (see Figure 1) was as

Figure 1. Illustration of the trial sequence for the (A) S–S association phase, (B) forced choice trials in Phase 2, and (C) free choice trials in Phase 3 for both the experiments. “Wald” is the German word for forest that was used as a stimulus since the participants were German native speakers. For illustrative purposes, the text that is not colored is displayed in black with a white background; however, the experiment had a black screen with the text displayed in color in Experiment 1a and white in Experiment 1b.

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follows: First, a fixation cross was displayed for 500 ms and the S2 was displayed for a fixed amount of 500 ms followed by the number 4 or 8 presented in the center of the screen until the response was given. Participants received error feedback and were asked to press the correct key, and they were warned if they took longer than 2,000 ms to respond. Phase 3 contained only free choice trials where participants guessed what number they expected to appear after a particular word. S1 or S2 words could appear in Phase 3. Participants were informed of the accuracy rate for S2 guesses in the free choice trials at the end of Phase 3. In total, this phase consisted of 80 trials, 40 with S1 and 40 with S2. The trial sequence was similar to Phase 2, wherein after the display of fixation cross for 500 ms, either S2 words were again presented visually for 500 ms or S1 pseudowords were presented auditorily for 800 ms (which was the length at which the audio words could be heard clearly). Both, words (S2) and pseudowords (S1), were followed by “?”, and we asked participants to freely choose the response by pressing the relevant response key depending on the number they guessed should have appeared (Figure 1). After Phase 3, a short cued recall test regarding the S1–S2 pairs and a questionnaire followed. This test consisted of two trials where each trial started with a fixation cross for 500 ms followed by S1 for 800 ms. After this, a “?” appeared for 800 ms followed by a question asking what word should have appeared with three options: One option was the correct associated S2 and the other two options were the other remaining S2 word and “do not know,” the order in which the options were presented on screen was randomly generated for each stimulus. We asked the participants to press the number corresponding to the option containing the correct associated S2. For Experiment 1b, only two options were shown, as the “do not know” option was removed. After the cued recall test, a questionnaire in German followed where we asked questions concerning their level of concentration and whether they had the impression that they learnt a new language. The questions (translated) were as follows: “During the study, did you have any distractions?” and “Did you learn a word from a new language?”, which could have meant that they transferred the semantic meaning of the German word that followed the pseudoword. We instructed the participants to respond in a forced choice yes/ no manner where they were asked to press “j” if yes, “n” if no, and “k” if they are unsure or do not know. Additionally, we assessed awareness of S2-R contingency also in the form of a questionnaire. The questions (translated) were as follows: “What number mostly occurred with Haus/

Wald?” The question was presented on the screen, and participants were asked to respond by pressing the key, 4 if the response is 4, 8 if the response is 8, and “k” if they do not know. Finally, questions regarding the possible response guess for S1 were also presented: “What number do you think could have occurred with mank/dels” (presented auditorily; response options: 4, 8, k for do not know)? In Experiment 1b, the do not know option was removed to have a more direct measure of awareness.

Design In Phase 2, contingency learning between S2-R contingencies was analyzed by comparing the performance (in reaction time and error rates) in valid (90%) and invalid (10%) trials. In Phase 3, the performance was assessed by measuring the proportion of response choices that corresponded to valid contingent responses. Hence, for S2 words, free choice performance served as an additional check for contingency learning (direct response activation). To test the hypothesis, the performance of S1 free choice trials (S1 Transfer) was analyzed to check whether participants transferred the valid contingent response of the associated visual S2 to auditory S1,

thus assessing the indirect response activation effects.

Data Analysis We used R (version 4.1.2; R Core Team, 2022) for all our analyses, namely packages stats (v4.2.1) for the analysis concerning the direct and indirect retrieval effects and lme4 for the analyses using the multilevel modeling to assess the role of awareness.