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Objective and subjective measures of cross-situational learning

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ABSTRACT

Statistical learning is often considered to be automatic and implicit, but little is known about the extent to which the resulting representations are available to conscious awareness. In the present study, we focus on whether the knowledge acquired in statistical learning of word–referent pairs is available to conscious control. Using a cross-situational learning paradigm, adult participants were first exposed to a set of pictures associated with auditorily presented words. Immediately thereafter, they were exposed to a second set of word-picture pairs. After the exposure phase, learning and conscious accessibility to the acquired knowledge were measured by using an adaptation of the Process Dissociation Procedure (Jacoby, 1991): two recognition tasks that only differed by instructions. In the Inclusion task, participants were instructed to accept all the correct associations (either from the first or the second set) and reject all the incorrect associations. In the Exclusion task, they had to accept all the correct associations from one of the sets and reject both the correct associations from the other set as well as all incorrect associations. Moreover, binary confidence judgments were recorded after each trial. Results show that participants were able to control the acquired knowledge. However, confidence judgments revealed that participants correctly identified the learned associations even when they claimed to guess, suggesting that cross-situational learning involves a mixture of both conscious and unconscious influences.

1. Introduction

When learning a new language, infants, as well as second-language learners, are often confronted with less-than-perfect matches between word occurrences and their referents in a natural setting, as it may often be the case that learners are surrounded by several potential concrete referents when hearing a new word. In the same way, more than one word candidate can often be attached to a given element present in the environment. The process of learning new associations between words and their referents is thus inherently statistical.

Congruently, studies performed in the field of cross-situational learning (CSL) have shown that learners are sensitive to the co-occurrence frequencies between words and objects (Frank, Goodman, & Tenenbaum, 2009; Smith & Yu, 2008; Vouloumanos, 2008; Yu, Ballard, & Aslin, 2005; Yu & Smith, 2007). In a typical experiment, learners are simultaneously exposed to several words and to their potential referents, presented without any associative cue. For example, a naïve participant may successively hear the words 'ball' and 'bat' while seeing, at the same time, a ball and a bat. A single trial does not provide enough information to decide whether the word /bat/ refers to one object or the other. However, if in another trial the same participant hears the words /bat/ and /dog/ while seeing a bat and a dog, he or she may now combine the conditional probabilities of co-occurrences across trials, and correctly map /bat/ to its referent. He or she even has enough information to associate the words /bat/ and /dog/ to their concrete counterparts.

Despite the limited number of repetitions of each word-picture association, adults (Kachergis, Yu, & Shiffrin, 2009; Yu & Smith, 2007; Yurovsky & Yu, 2008), as well as young children (Akhtar & Montague, 1999; Fisher, Hall, Rakowitz, & Gleitman, 1994; Smith & Yu, 2008; Vouloumanos & Werker, 2009; Yu & Smith, 2011), are able to learn the correct matching between words and pictures. CSL can then be defined as the ability to learn word–referent mappings by tracking co-occurrences across multiple ambiguous associations. In the current study, we explored the extent to which the knowledge of word–referent pairs acquired during CSL is available to consciousness.

Little is known concerning the automaticity of CSL. Does it occur incidentally, through mere exposure, or does it require an explicit intention to learn? Kachergis, Yu, and Shiffrin (2014) addressed this issue in a recent study in which they successively tested participants under (1) incidental instructions asking them to memorize each word and each object, and (2) explicit instructions asking them to learn the meanings of the words. Results showed successful word learning in the two conditions, but performance was improved under explicit instructions. CSL can thus occur incidentally even though explicit instructions improve performance.

In another statistical word learning study, Hamrick and Rebuschat (2012) explored the impact of intentional versus incidental instructions on both general performance and the level of awareness of the acquired knowledge. Similar to Kachergis et al. (2014), they found that the

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general level of performance was improved by intentional instructions to learn the word/referent associations. Importantly, they found successful implicit learning under both incidental and intentional instructions, but participants only acquired explicit knowledge in the intentional condition.

Taken together, these studies suggest that CSL is based on both implicit and explicit knowledge, and that learning conditions have an impact on the extent to which the acquired knowledge can be accessed consciously. Interestingly, under intentional learning conditions participants acquired both conscious and unconscious knowledge of the word–referent pairs.

In the present study, we measured whether the knowledge acquired during CSL is amenable to conscious control. To do so, we adapted the Process Dissociation Procedure (PDP; Jacoby, 1991) in which conscious and unconscious influences are estimated from the comparison of two situations in which these influences either both contribute to performance — the inclusion task — or are set in opposition — the exclusion task. Consider, for example, a CSL experiment in which participants are first successively exposed to words from two different lists (list 1 and list 2), each paired with identical pictures, and asked to memorize the associations. Each picture is thus associated with two different words. Second, participants are asked to perform a recognition task under inclusion instructions, in which they are asked to identify correct associations, that is, correct word–picture pairs stemming from either list 1 or list 2. In this situation, correct responses may either be based on conscious recollection of a specific association *or* on a mere feeling of familiarity with the fact that an object was associated with a given word during exposure (irrespective of the list to which it belongs). Third, participants have to perform the same task again, but under exclusion instructions: Participants are now instructed to identify correct associations stemming from list 1 (respectively, from list 2) but to exclude associations stemming from list 2 (respectively, from list 1). Under such instructions, successful performance can only be based on conscious recollection of the target association, for the only way to successfully follow the instructions is to consciously remember the list to which the word belongs. Merely knowing a word/referent association (but not the list it belongs to) will instead lead participants to erroneously accept an association from list 2 (respectively, from list 1). In contrast to what is the case under inclusion instructions, familiarity and recollection thus act in opposition in the exclusion task. Analyzing the probability of selecting an item under exclusion and inclusion instructions therefore makes it possible to estimate the independent contributions of both recollection — or conscious — and familiarity — or automatic — processes to performance.

In a series of implicit learning studies, the comparison between inclusion and exclusion performance has been used to estimate the extent to which learning was, in fact, amenable to conscious control (e.g. Destrebecqz & Cleeremans, 2001, 2003; Dienes, Altmann, Kwan, & Goode, 1995; Jiménez et al., 2006; Kane, Picton, Moscovitch, & Winocur, 2000; Reingold, 1995). Recently, we used an adaptation of the PDP in a statistical speech segmentation paradigm (Franco, Cleeremans, & Destrebecqz, 2011) and showed that participants presented with two different artificial languages presented successively were able (1) to extract the words of both languages from the continuous speeches and (2) to follow inclusion and exclusion instructions, suggesting that they were able to control the acquired knowledge.

The interpretation of the PDP remains controversial, however. For Rünger and Frensch (2010), the operational definition of consciousness used in the PDP is too restrictive, as the main function of consciousness is to enable global availability to various cognitive processes and not merely to cognitive control. In order to address this issue, subjective measures, such as confidence judgments, can be used in conjunction with the PDP to obtain a first-person assessment of conscious learning (Cheesman & Merikle, 1984; Dienes & Berry, 1997; Fu, Fu, & Dienes, 2008; Tunney & Shanks, 2003). Different methods can be used to assess awareness. The *guessing criterion* rests on the idea that knowledge is unconscious when performance is above chance while participants claim to guess (Dienes & Berry, 1997; Dienes et al., 1995). According to the *zero-correlation criterion* (Chan, 1992), if participants are conscious of the acquired knowledge, they should also be more confident when they give correct responses than when they make errors. Thus, performance will be considered as being based on conscious knowledge when confidence and accuracy are positively correlated, while the absence of relationship between these two variables would reflect the influence of unconscious knowledge. In the present study we used a binary confidence scale to measure subjective confidence, based on the idea that a binary scale is more sensitive to low levels of awareness, compared to continuous ratings (Tunney & Shanks, 2003; see also Tunney, 2005). This measure was combined with an adaptation of the PDP in order to precisely assess the role of conscious and unconscious processes in CSL.

2. Method

2.1. Participants

Forty-eight French-speaking undergraduate psychology students (mean age: 21.3; 34 females) were included in this study and received class credits for participation. None of them had previous experience with the artificial languages presented in this experiment. All reported no hearing problems.

2.2. Material

Twelve pictures of unknown non-objects (visual stimuli) and two lists of 12 pseudo-words (auditory stimuli) were created (see Fig. 1). The non-objects were single 2D colored outline drawings previously designed to match real objects (Urbain et al., 2013). Thus, although the visual stimuli were unknown, they had the physical properties of familiar objects. Each list of auditory stimuli was composed of French-like bisyllabic nonsense words. Each visual stimulus was associated with two auditory stimuli: one from the L1 list of words and another from the L2 list of words. Each nonsense word was produced by a French female voice. In order to ensure that both sets of associations were equally learned when presented in isolation, we first conducted a control experiment in which participants (N = 18) were randomly exposed to either an L1 or L2 set of associations. Learning was measured by means of a recognition task of the word–referent associations. Results showed that performance did not differ as a function of set, $t(17) = -.365$, $p > .5$. Both were performed above chance level ($M = 85.64\%$ $SD =$

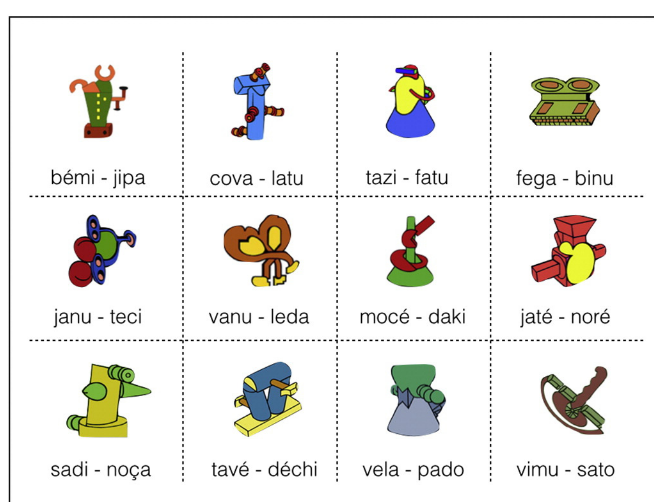

Fig. 1. The twelve stimulus shapes and their referents in sets 1 and 2.