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The Role of Statistical Learning and Working Memory in L2 Speakers' Pattern Learning

KIM MCDONOUGH
Concordia University
Department of Education
1455 de Maisonneuve Blvd W
Montreal, Quebec H3G 1M8
Canada
Email: kim.mcdonough@concordia.ca

PAVEL TROFIMOVICH
Concordia University
Department of Education
1455 de Maisonneuve Blvd W
Montreal, Quebec H3G 1M8
Canada
Email: pavel.trofimovich@concordia.ca

This study investigated whether second language (L2) speakers' morphosyntactic pattern learning was predicted by their statistical learning and working memory abilities. Across three experiments, Thai English as a Foreign Language (EFL) university students ($N = 140$) were exposed to either the transitive construction in Esperanto (e.g., *tauro batas cevalon*, "bull hits horse") or the nonprototypical English double-object dative construction (e.g., *John built the table a leg*). They also completed an aural test of statistical learning and a spoken backward digit-span test of working memory. In Experiment 1, only statistical learning was predictive of Esperanto pattern learning. Experiment 2 targeted pattern learning of the English nonprototypical double-object dative construction. Although working memory was associated with performance in the exposure phase, only statistical learning predicted test performance, as in Experiment 1. Finally, Experiment 3 served as a control condition in which participants were exposed to prototypical datives only during the exposure phase. This experiment showed that neither statistical learning nor working memory were associated with exposure or test performance. The findings are discussed in terms of the engagement of statistical learning and working memory during L2 pattern learning.

Keywords: L2 pattern learning; statistical learning; working memory

CONSTRUCTION LEARNING STUDIES CARried out by Goldberg and colleagues have shown that first language (L1) speakers of English can comprehend and produce the novel construction of appearance (N_1N_2V), with the corresponding meaning of N_1 'appears in/on' N_2 (e.g., *the spot the king moopoed*) after relatively brief language exposure (Boyd, Gottschalk, & Goldberg, 2009; Casenhiser & Goldberg, 2005; Goldberg & Casenhiser, 2008; Goldberg, Casenhiser, & Sethuraman, 2004; Goldberg, Casenhiser, & White, 2007). However, construction learning studies with second language (L2) speakers have reported far greater variability with a variety of constructions, including the appearance construction and Samoan ergative constructions (Nakamura, 2012), Esperanto transitives (Fulga & McDonough, 2016; McDonough & Fulga, 2015; McDonough & Trofimovich, 2013, 2015), and English datives (McDonough & Nekrasova–Becker, 2014; Year & Gordon, 2009). These studies have shown that L2 speakers experience considerable difficulty when learning new patterns. Researchers have speculated that a variety of factors may account for this difficulty, including the explicitness of the classroom learning environment (Year & Gordon, 2009), L1 background (Fulga & McDonough, 2016; McDonough & Fulga, 2015), processing strategies (Fulga & McDonough, 2016; McDonough & Trofimovich, 2015), and task instructions (McDonough & Trofimovich, 2013).

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In light of the difficulty that L2 speakers have shown with pattern learning, an interesting question is whether individual differences, specifically statistical learning and working memory, could help account for variability in their success. Broadly defined as the ability to discover patterns (Romberg & Saffran, 2010), statistical learning has been implicated in many linguistic domains, including speech segmentation (Saffran, Aslin, & Newport, 1996), phonetic learning (Maye, Werker, & Gerken, 2002), detection of morphological patterns (Pacton et al., 2001), and syntactic generalizations (Gómez & Lakusta, 2004), as well as visual and tactile learning (C. M. Conway & Christiansen, 2005; Fiser & Aslin, 2002). The human capacity to extract regularities is so pervasive that statistical learning has been dubbed a robust mechanism for detecting patterns and generalizing them to novel contexts (Aslin & Newport, 2012).

With respect to learning morphosyntax, for example, Gómez (2002) showed that both infants and adults could learn structural co-occurrences in a miniature artificial language after brief exposure (i.e., 3 minutes for infants and 18 minutes for adults). Such co-occurrences (e.g., *pel*-x-*rud*, where "x" designates an unrelated word drawn from a lexical set) are similar to morphosyntactic structures in natural languages that span irrelevant intervening content, such as dependencies in number agreement (e.g., *The leaves on a tree are turning yellow*) or between free and inflectional morphemes (e.g., *The package was delivered on time*). People vary in their capacity for statistical learning, with both adults and children showing variation in their ability to extract patterns in auditory stimuli and visual arrays. Statistical learning also varies across the lifespan. For instance, Arciuli and Simpson (2011) showed that L1 children's ability to extract visual patterns improves between the ages of 5 and 12. Finally, statistical learning also varies in speakers with different neurological and developmental conditions (e.g., Christiansen et al., 2010; Plante, Gómez, & Gerken, 2002; Pothos & Kirk, 2004).

As for its potential role in learning, Misyak and Christiansen (2012) recently demonstrated that statistical learning, measured through an auditory sequence learning task, was positively associated with adults' scores in L1 language comprehension tests targeting the interpretation of subject–object relative clauses and sentences with ambiguous homonyms. In fact, statistical learning emerged as the only predictor of comprehension after contributions of memory, intelligence, and linguistic factors were controlled. Using a similar sequence learning task, Brooks and Kempe (2013) found an association between statistical learning and L2 speakers' awareness of underlying regularities in Russian case marking. Measuring L2 speakers' ability to detect both auditory and visual patterns, Granena (2013) found that auditory sequence learning was associated with early L2 learners' performance on a metalinguistic knowledge test, while visual sequence learning facilitated late L2 learners' performance on a word monitoring task. Because pattern detection requires that speakers attend to morphosyntactic regularities, statistical learning (as measured through sequence learning tasks) could therefore mediate the extent to which speakers succeed in acquiring L2 constructions.

Another individual difference that may contribute to L2 speakers' pattern learning is working memory. Working memory is the ability to maintain, update, and manipulate information over short delays, which requires executive attention. Individuals with a large working memory capacity are more able to control their attention, which allows them to achieve task goals even if there is distracting or irrelevant information (A. R. Conway, Cowan, & Bunting, 2001; Kane et al., 2001; Unsworth, Schrock, & Engle, 2004). Working memory is typically measured through span tests (e.g., reading span, digit span) that require speakers to maintain and process increasingly longer sequences of information while performing another task, such as recalling the final word in a sentence or reordering digits (e.g., Daneman & Carpenter, 1980; Engle et al., 1999). Such measures of working memory have been shown to relate to L2 users' performance in various domains, including grammar, vocabulary, reading, speaking, and listening (e.g., Geva & Ryan, 1993; Harrington & Sawyer, 1992; Kormos & Sáfár, 2008).

With respect to the processing and learning of morphosyntax, working memory capacity seems to underpin at least some aspects of speakers' ability to identify patterns, particularly when it comes to agreement morphology. For example, Kapa and Colombo (2014) recently demonstrated that L2 speakers' working memory predicted their success in learning a novel artificial grammar. Furthermore, focusing specifically on gender agreement violations in Spanish, Sagarra and Herschensohn (2010) found that L2 speakers with higher working memory scores were more sensitive to violations than speakers with lower working memory scores (see also Coughlin & Tremblay, 2013; Havik et al., 2009). Working memory was also found to have an independent contribution to L1 English speakers' ability to learn the relationship between grammatical gender and morphological case marking in Russian (Brooks, Kempe, & Sionov, 2006; Kempe & Brooks, 2008). Similarly, working memory was shown to be positively associated with L1 Japanese speakers' performance on grammaticality judgment and production tests following incidental exposure to three constructions in Samoan through reading for comprehension (Robinson, 2005). In sum, working memory capacity might moderate L2 pattern learning, with higher working memory capacity facilitating the ability to identify the relevant recurrent patterns while disregarding nonessential information.

To summarize, following from the difficulties that L2 speakers face and the variability in their performance when learning new morphosyntactic patterns, it seems plausible that statistical learning and working memory could play a role in pattern learning. Statistical learning likely captures speakers' ability to acquire repeated regularities, which would facilitate the ability to learn morphosyntactic patterns. Similarly, working memory reflects the amount and type of information that speakers are able to attend to, which may be associated with the ability to track morphosyntactic regularities across diverse stimuli. Therefore, the chief goal of the current study was to explore possible relationships between L2 pattern learning and L2 speakers' statistical learning and working memory abilities. To understand how statistical learning and working memory relate to L2 speakers' success at learning patterns under different conditions, morphosyntactic constructions in both a novel L2 (Esperanto in Experiment 1) and a familiar L2 (English in Experiments 2 and 3) were tested. The goal of Experiment 1, which targeted the learning of Esperanto transitives, was to examine how L2 speakers approach the learning of a novel morphosyntactic structure in an unfamiliar language (i.e., in the absence of prior knowledge of the target construction and familiarity with the target language). Experiment 1 addressed the following research question:

RQ1. Do statistical learning and working memory predict L2 pattern learning in a novel language?

EXPERIMENT 1

Participants

The participants were 47 L2 English speakers (26 women, 21 men) studying at a university in northern Thailand. They were second-year students with a mean age of 19.2 years ($SD = .7$) and a mean of 14 years ($SD = 1.2$) of prior English study within Thailand. Most participants had never visited an English-speaking country (43), but some reported stays of less than a few weeks (3) or greater than 1 month (1). In terms of their knowledge of additional languages besides Thai and English, 8 students reported having basic knowledge of French (5), Japanese (1), Chinese (1), or Italian (1). They were studying undergraduate degrees in the faculties of visual and fine arts (25), medical technology (11), humanities (9), and science and engineering (2).

Target Structure

The target structure was the Esperanto transitive construction, which involves both morphological and syntactic features. In terms of morphology, the suffix *–n* is added to mark nouns that function as objects. For example, the word horse (*cevalo*) appears without a suffix when it functions as the subject but receives the *–n* suffix when it functions as the object (*cevalon*). In terms of syntax, word order in Esperanto transitive constructions is variable. Although a variety of word orders are possible, the most commonly used are SVO and OVS (Cox, 2011; Harlow, 1995), as in *tauro batas cevalon* and *cevalon batas tauro* (bull hits horse). The Esperanto transitive construction was considered novel for the participants because they had no prior exposure to Esperanto, both Thai and English have SVO word order, and neither Thai nor English has accusative case marking on nouns.

Design

The study adopted a predictive associational design to determine whether statistical learning and working memory contribute to L2 speakers' pattern learning. The predictor variables were statistical learning, which was defined as the participants' ability to recognize nonadjacent dependencies, and working memory, which was operationalized as their performance on the backward digit span test. The outcome variable was pattern learning, which was operationalized as the ability to correctly identify the meaning of the Esperanto transitive construction.

Materials

The materials included exposure and test materials for the Esperanto transitive construction, along with tests of statistical learning and working memory.

Esperanto Materials. The Esperanto materials consisted of a picture identification task divided into exposure and test phases based on items used in previous studies (Fulga & McDonough, 2016; McDonough & Fulga, 2015; McDonough & Trofimovich, 2013, 2015). For the exposure phase, the participants listened to 24 simple Esperanto transitive sentences (12 SVO, 12 OVS) and chose one of two images (printed side-by-side on paper) that correctly depicted the meaning of each sentence. The sentences were created from six nouns (*tauro* [bull], *makropo* [kangaroo], *kato* [cat], *kapro* [goat], *cevalo* [horse], and *pilko* [tennis ball]), each used four times as an object, and two verbs conjugated in the present tense (*batas* [hit], *pelas* [chase]). The meanings of the words were practiced in an immediately preceding vocabulary activity, with all participants performing at or near 100% accuracy.

The sentences were organized in four sets of six sentences (3 SVO, 3 OVS). The sets were designed to direct participants' attention to different components of the two picture alternatives: completely different nouns (Set 1), different verbs (Set 2), different subjects (Set 3), and different objects (Set 4). For example, in Set 1, the sentence *cevalo pelas katon* (SVO [horse chases cat]) occurred with a picture of a bull chasing a goat and a horse chasing a cat. In contrast, in Set 4, the sentence *cevalon batas kapro* (OVS [goat hits horse]) occurred with a picture of a goat hitting a horse and a goat hitting a cat. Immediately following the exposure items, the test phase presented 12 spoken sentences (6 SVO, 6 OVS) paired with images of reversible events. For example, the sentence *tauro batas kapron* (SVO [bull hits goat]) was paired with a picture of a bull hitting a goat and a goat hitting a bull. In sum, for the exposure items, the participants could rely on lexical knowledge to select the correct pictures, but they required knowledge of the structural (variable word order) and morphological (*–n* suffix) features of the Esperanto transitive to answer the test items correctly. All exposure and test sentences (see Appendix A) were recorded by a female L2 English speaker, with each sentence spoken twice and presented at the rate of 7 seconds per item using PowerPoint. Instrument reliability of the Esperanto materials (Cronbach's α) was .76.

Statistical Learning Test. The statistical learning test, adapted from Gómez (2002), measured the participants' ability to detect nonadjacent dependencies. The test targeted two nonadjacent dependencies created from four English-sounding nonce words that were organized into two patterns: *pel*-x-*rud* and *vot*-x-*jic*, where "x" designates an unrelated nonce word drawn from a lexical set. During the exposure phase, 12 nonce words were inserted into each pattern to create 24 unique, three-word sequences that were played twice, for a total of 48 sequences. For the test phase, 16 novel sequences were created by inserting four previously unheard nonce words into each pattern and varying the pairings of *pel*, *rud*, *vot*, and *jic*, such that eight test items followed the same two patterns presented during the exposure phase (i.e., *pel*-x-*rud*, *vot*-x-*jic*) while eight items violated the patterns (i.e., **pel*-x-*jic*, **vot*-x-*rud*). All sentences were recorded by a male L1 English speaker, organized into two randomizations with a 250-millisecond interval between each of the three sequence elements, a 3-second pause between exposure sequences, and a 6-second pause between test sequences, and presented aurally using PowerPoint. The participants indicated whether the test items followed or diverged from the patterns presented during the exposure phase, and their correct responses were summed (for a maximum score of 16). Two rounds of pilot testing were carried out with English L1 speakers ($N = 29$), yielding reliability values (Cronbach's α) of .85 and .71. The test was administered to English L2 speakers ($N = 50$) as part of another study (McDonough et al., 2016), with a reliability of .75. Although reliability for the current experiment was lower (α = .51), it surpassed the threshold considered acceptable for cognitive individual differences tests, with "a Cronbach α above .4 or .5 (. . .) taken as reasonable support for the internal reliability of a test" (Reber, Walkenfeld, & Hernstadt, 1991, p. 893).

Working Memory Test. The digit span backwards task from the Wechsler Adult Intelligence Scale, WAIS-III (Psychological Corporation, 1997), was used to measure working memory. In this task, listeners hear digit sequences of increasing length and repeat each sequence in the reverse order. Because working memory capacity is thought to be language independent but may be subject to effects of language proficiency if tested in the L2 (Osaka & Osaka, 1992; van den Noort, Bosch, & Hugdahl, 2006), the test was carried out in Thai, the participants' L1. The digits were recorded by a male L1 Thai speaker and were organized into 20 digit sequences of increasing length (between 2 and 10 digits), with two sequences of each length. The sequences were presented to participants at the rate of one digit per second through PowerPoint, in one of two randomized orders, and the participants' task was to repeat each sequence (e.g., 0–4–2–9–6–3–1) in the reverse order (i.e., 1–3–6–9–2–4–0). Participants were given one point for each correctly repeated sequence, and all points were summed to derive the total working memory score (maximum score of 20). The task was terminated when the participant incorrectly repeated both samples of a given length or correctly repeated both sequences of length 10. The test was administered to L2 English speakers ($N = 50$) as part of another study (McDonough et al., 2016), with a reliability of .69. The test reliability for the current experiment was .57.

TABLE 1
Descriptive Statistics for Predictor and Outcome Variables

Variable	*M*	*SD*	95% *CI*
Statistical learning	8.66	2.93	7.80, 9.52
Working memory	5.62	1.73	5.11, 6.12
Esperanto exposure ($n = 24$)	20.55 (86%)	3.57	19.51, 21.60
Esperanto test ($n = 12$)	6.34 (53%)	1.52	5.89, 6.79

Procedure and Analysis

The research materials were administered during 50 minutes of one regularly scheduled English as a foreign language (EFL) class. The working memory test was administered first (10 minutes), and each participant was given a digital audio recorder to record their spoken digit spans. After the audiorecorders were collected, the statistical learning test was administered (10 minutes). The participants were informed that they would hear 48 short sentences made from English-sounding words that had no meaning. Their task was to listen carefully to the sentences because there would be a related activity afterwards. After listening to the sentences, the participants were told that they would hear 16 new sentences, only some of which followed the same patterns of the previous sentences. Their task was to decide whether each new sentence was the same or different as the patterns in the previous sentences. After completing the statistical learning test, the Esperanto task was carried out (20 minutes). The exposure items were presented in four sets of six items, and the participants were told what elements of the sentence to focus on in order to select the correct pictures. For example, before listening to the first six items, they were told that they only had to know one noun in the sentence to be able to identify the correct picture. Before each subsequent set, the participants were told what element in the sentence to pay attention to (i.e., the verbs, subjects, or objects), and that the items would get increasingly more difficult and that they should pay attention to the endings of the nouns in order to understand Esperanto grammar. Prior to listening to the test items, the participants were told that the last 12 sentences were the most difficult, and that they had to understand Esperanto grammar in order to answer correctly. After completing the Esperanto items, the participants answered a brief questionnaire (10 minutes) in which they were asked to create sentences in Esperanto using new vocabulary items to describe new images and to explain the grammar of Esperanto sentences. The remaining class time (25 minutes) was used for listening activities that were not related to the goals of the current study.

The participants' performance on the statistical learning test and the working memory test was coded by summing the number of correct responses. For the Esperanto test, which consisted of 12 forced-choice picture identification items, the number of correct picture identifications were summed. High scores (maximum score of 12) indicated the ability to rely on inflected morphology, as opposed to word order, to interpret Esperanto transitives. A stepwise multiple regression model was computed with test performance as the outcome variable. Performance on the exposure phase (to control for baseline knowledge) was entered in the first step, and working memory and statistical learning were entered in step two. Alpha was set at .05.

Results and Discussion

The participants' scores for the cognitive tests and for the Esperanto exposure and test items are provided in Table 1. For the Esperanto exposure items, which could be identified correctly using lexical knowledge, the participants were largely accurate for both SVO and OVS items (20.55/24). In other words, when they were able to rely on lexical meaning, the participants were able to correctly identify the images regardless of word order. However, on the test items that required knowledge of the structural and morphological features of the transitive construction, the partici-

TABLE 2
Esperanto Correlation Coefficients

Variable	2	3	4
1. Esperanto learning	.08	.01	.21
2. Esperanto test	–	.51*	.18
3. Statistical learning		–	.07
4. Working memory			–

Note. *$p < .05$.

pants scored higher on the SVO items (5.38) than the OVS items (.96). Although the participants successfully identified images when the items occurred in SVO word order, fewer participants were able to identify the correct pictures when the test sentences occurred with OVS word order.

To address the research question, which asked whether statistical learning and working memory were associated with L2 pattern learning, a stepwise multiple regression analysis was carried out. The correlations among the Esperanto outcome and predictor variables are shown in Table 2. The only significant correlation was between statistical learning and Esperanto test performance.

Esperanto learning scores were entered into the regression model first in order to control for baseline knowledge of the structure. Statistical learning and working memory scores were entered together in the next step, to determine their unique contribution to predicting test performance. The final model was statistically significant, $F(3,46) = 5.46$, $p = .003$, and accounted for a total of 23% of the variance in Esperanto test performance ($R^2 = .28$, adjusted $R^2 = .23$). Performance on the exposure items did not contribute to explaining Esperanto test scores ($R^2 < .01$). However, the entire proportion of the explained variance in Esperanto test performance (23%) was associated with statistical learning, but not working memory (see Table 3). As shown by a positive beta value, this relationship was positive, such that greater statistical learning scores were associated with higher Esperanto test performance.

To summarize, statistical learning was a significant predictor of Esperanto pattern detection but working memory was not. The null finding for working memory may be due to the incidental or implicit nature of the pattern learning task. Previous studies of implicit learning have not found relationships with working memory unless participants are given explicit instructions to search for or identify variation (Kaufmann et al., 2010; Unsworth & Engle, 2005), such as when participants experience input under rule-search learning conditions (e.g., Tagarelli, Borges Mota, & Rebuschat, 2011). It is possible that the instructions given to the participants during the exposure phase were not sufficiently explicit to engage working memory. Additional evidence that the learning task may have been more implicit or incidental is provided in the participants' responses to the exit questionnaire. Only 2 of the 47 participants were able to generate grammatically correctly Esperanto sentences in both word orders and articulate the morphosyntactic features of Esperanto. In other words, the ability to correctly identify Esperanto sentences during the test phase was not contingent upon the participants' having explicit, reportable knowledge of the relevant morphosyntactic patterns. Alternatively, the null finding for working memory could be related to the relatively low processing demands imposed on working memory capacity by the Esperanto sentences. All Esperanto sentences were only three words long and were spoken twice. In essence, working memory contributions to pattern learning of a novel morphosyntactic pattern may have been negligible because the processing involved in the experimental tasks imposed little burden on the speakers. This finding is in line with prior research reporting no relationships between working memory and morphosyntactic processing under nontaxing processing conditions (Felser & Roberts, 2007; Havik et al., 2009; Juffs, 2005).

Unlike working memory, statistical learning was positively associated with the participants' learning of the Esperanto transitive construction. One possibility is that the predictive relationship was an artifact of underlying similarity in the testing instruments. For Esperanto transitives, the key relationship was the argument roles of N_1 and N_2, which were always separated by a verb. Similarly, the key element in the statistical learning test was the co-occurrence of two target elements separated by an unrelated nonce word. In other words, the positive relationship between statistical learning and Esperanto test items may simply reflect similarities in measurement. An alternate possibility is that statistical learning underpins L2 speakers' ability to learn novel patterns, regardless of any similarity in the instruments used to test pattern learning and statistical learning.

In order to further investigate whether working memory and statistical learning play a role in L2 pattern learning, Experiment 2 investigated a new pattern, the nonprototypical double-object dative construction, in a more familiar L2, which was English. By using a more familiar L2, the expo-

TABLE 3
Summary of Regression Model for Esperanto

Predictor	B	$SE\ B$	95% CI	β	t	p	ΔR^2
Step 1: Esperanto exposure	.03	.06	−.10, .16	.08	.52	.609	.01
Step 2: Statistical learning	.26	.07	.12, .39	.50	3.80	.001	.23
Step 3: Working memory	.11	.12	−.12, .35	.13	.97	.337	

sure and test items could be longer, which would help clarify whether the relationship between statistical learning and Esperanto was simply due to the measurement similarity (i.e., both based on three-word utterances). Furthermore, using longer language strings would also provide insight whether working memory failed to engage during Esperanto pattern learning because the stimulus sentences were too short to be cognitively demanding. Therefore, Experiment 2 addressed the following research question:

RQ2. Do statistical learning and working memory predict pattern learning in a familiar L2?

EXPERIMENT 2

Participants

The participants were 58 English L2 speakers (48 women, 10 men) studying at the same university in northern Thailand as the participants in Experiment 1. They were second-year students with a mean age of 19.4 years ($SD = 1.6$) and reported a mean of 13.9 years of prior English study ($SD = 2.3$) within Thailand. Most participants had never visited an English-speaking country (50), but some reported stays of less than a few weeks (5) or greater than 1 month (3). In terms of their knowledge of additional languages besides Thai and English, nine students reported having basic knowledge of Chinese. They were studying undergraduate degrees in the faculties of medicine (34), science (13), and social sciences and humanities (11).

Target Structure

The target structure was the nonprototypical double-object dative construction, in which inanimate nouns occur as both the object and the recipient. The core meaning of the double-object dative is the transfer of possession of an object to a goal, which prototypically is a human recipient or a beneficiary. In its prototypical usage, the recipient/beneficiary conveys given information and is expressed as a pronoun, as in *Mr. Smith enjoyed teaching students about chemistry. But they had a lot of problems with the last exam, so he told them the answers.* In contrast, the nonprototypical construction expresses both the recipient and the object undergoing a transfer of possession as inanimate noun phrases (e.g., *John's children broke a table while they were playing. It was his favorite table, so John built the table a leg*). Double-object datives with inanimate recipients are less frequent in naturally occurring talk than datives with animate recipients (Bresnan, 2007; Gries, 2003), although they occur more often in New Zealand English than American English (Bresnan & Hay, 2008). Both L1 and L2 English speakers tend to rate double-object datives with inanimate recipients as less acceptable than those with animate recipients, but do not categorically reject them (Gropen et al., 1989; Sawyer, 1996). Furthermore, pilot testing of similar nonprototypical dative items as part of a previous study (McDonough & Nekrasova–Becker, 2014) indicated that L1 English speakers were able to correctly identify the recipient with 100% accuracy.

Materials. The statistical learning and working memory tests were identical to those in Experiment 1. For Experiment 2, reliability (Cronbach's α) was .56 for the statistical learning test and .79 for the working memory test. Similar to the Esperanto materials used in Experiment 1, the dative materials consisted of a picture identification task divided into exposure and test phases, using items adapted from previous research (McDonough & Nekrasova–Becker, 2014). For the exposure phase, the participants listened to 18 prototypical and 6 nonprototypical double-object dative sentences embedded in a short discourse context that established the recipient as given information, and chose one of two images (printed side-by-side on paper) which correctly depicted the meaning of each sentence. The prototypical sentences were created from six dative verbs conjugated in simple past tense (*sent, taught, showed, told, owed, offered*), with each verb used from two to four times. The nonprototypical sentences were created from six verbs (*brought, fixed, saved, painted, threw, shipped*), with each verb used once.

The exposure sentences were organized into four sets designed to direct participants' attention to different components of the two picture alternatives: environmental or contextual features (Set 1), different subjects (Set 2), different objects (Set 3), and different recipients (Set 4). For example in Set 1 (different contextual features), the nonprototypical item "*John borrowed Grace's truck to go mountain biking for the weekend. When he returned it, Grace found a big scratch on the door. So she brought the truck some paint*" was paired with two pictures of a woman approaching a pickup truck holding a can of spray paint. In one picture, the pickup truck contained mountain bikes, while the other picture showed ski equipment. In Set 2 (different subjects), the prototypical item "*Johnny played on his school baseball team. Today he couldn't play because he forgot part of his uniform. So the coach offered him a hat*" was paired with images of a boy being handed a baseball hat either by a coach or a friend. Although the exposure phase included nonprototypical datives, the participants could identify the correct pictures by relying on other information in the sentences. The dative exposure items are provided in Appendix B.

Immediately following the exposure items, the test phase presented 12 spoken sentences with nonprototypical double-object datives created from new verbs (*threw, built, baked, cooked, fried, cut, wrote, promised, mailed, traded, fed, served*) that were embedded in short discourse contexts. Each sentence was paired with images of reversible events. For example, the item "*Irene's daughter thought her new dress was boring. But Irene couldn't afford another one. So she cut the dress some ribbons*" was paired with images of a woman kneeling beside a dress on a mannequin with ribbons on the floor. While one image showed the woman cutting the dress, the other image showed the woman cutting the ribbons. Whereas the participants could identify the pictures in the exposure phase by relying on animacy cues for the prototypical items (i.e., the recipient was human whereas the object was inanimate) and contextual clues for the nonprototypical items, the test phase required that they differentiate the function of two inanimate noun phrases based on word order. The dative test items are provided in Appendix B. All exposure and test items were recorded by a female L1 English speaker and presented aurally at the rate of 7 seconds per item using PowerPoint. Reliability of the dative items (Cronbach's α) was .62.

Procedure and Analysis

The research materials were administered during 50 minutes of one regularly scheduled EFL class. The working memory test (10 minutes) and the statistical learning test (10 minutes) were administered following the same procedures and instructions used in Experiment 1. After the statistical learning test, the dative task was carried out (20 minutes). The exposure items were presented in four sets of six items, and the participants were told what elements of the sentence to focus on in order to select the correct pictures, such as a contextual detail (Set 1), who was doing the action (Set 2), what they were doing (Set 3), or who was participating (Set 4). Prior to listening to the test items, the participants were told that the last 12 sentences were more difficult, and that they had to pay attention to all the relationships among the people and things in the sentences in order to answer correctly. After completing the dative items, the participants answered a brief questionnaire (10 minutes) in which they were asked to create sentences in English to describe four pictures previously shown as distractors and to explain the grammar of the English sentences they had heard. For the rest of the class time (25 minutes), the participants carried out listening activities unrelated to the goals of the current study.

The participants' performance on the statistical learning test and the working memory test was coded by summing the number of correct responses. For the dative test, the number of correct picture identifications were summed. High scores (maximum score of 12) indicated that the participants recognized the first noun after the verb as the recipient, as opposed to the direct object. A stepwise multiple regression model was computed with test performance as the outcome variable. Performance on the exposure phase (to control for baseline knowledge) was entered in the first step, and working memory and statistical learning were entered in step two. Alpha was set at .05.

Results and Discussion

The participants' scores for the cognitive tests and for the dative exposure and test items are provided in Table 4. For the exposure phase, the participants' mean score was 16.80/18 for prototypical items and 4.59/6 for nonprototypical items. Across both item types, the participants scored a mean of 21.19/24, or 88% accuracy. For the test phase, which included exclusively

TABLE 4
Descriptive Statistics for Predictor and Outcome Variables

Variable	*M*	*SD*	95% *CI*
Statistical learning	9.57	2.50	8.88, 10.26
Working memory	6.66	2.63	6.00, 7.31
Dative exposure ($n = 24$)	21.19 (88%)	2.43	20.55, 21.83
Dative test ($n = 12$)	7.86 (66%)	1.93	7.35, 8.37

TABLE 5
Dative Correlation Coefficients

Variable	2	3	4
1. Dative exposure	.19	.21	.42*
2. Dative test	–	.35*	.01
3. Statistical learning		–	−.01
4. Working memory			–

Note. *$p < .05$.

nonprototypical items that could not be identified by relying on animacy or contextual clues, the mean score was 7.86 out of 12, or 66% accuracy.

To address the research question, which asked whether statistical learning and working memory predicted L2 speakers' pattern learning, participants' statistical learning and working memory scores as well as their performance on the dative exposure items were used in a stepwise linear regression analysis. The correlations among the variables are shown in Table 5. The only significant correlations were between test performance and statistical learning and between dative exposure items and working memory.[1]

As in Experiment 1, exposure scores were entered first, followed by statistical learning and working memory scores. The final regression model was statistically significant, $F(3,56) = 3.16$, $p = .032$, and accounted for a total of 10% of the variance in dative test performance ($R^2 = .15$, adjusted $R^2 = .10$). Dative test performance was predicted by statistical learning only, with higher statistical learning scores associated with more accurate test performance (see Table 6).

In sum, the dative test performance of participants in Experiment 2 was predicted by statistical learning, but not by working memory, which confirms the findings of Experiment 1. Thus, the association between pattern detection and statistical learning in Experiment 1 does not appear to be due to similarity in the adjacency of the key elements targeted in the Esperanto and statistical learning tests. Even though the target structure in Experiment 2 was changed to the nonprototypical English double-object dative constructions, which allowed for much longer stimulus sentences than Esperanto, statistical learning was the only significant predictor of pattern learning. Taken together, the findings of Experiments 1 and 2 suggest that statistical learning ability may underlie L2 speakers' pattern learning, for completely novel patterns in a new L2, and for nonprototypical patterns in a more familiar L2. A remaining question, however, is whether the novel (nonprototypical) pattern must be present in the exposure phase in order for learning to occur. In other words, L2 speakers with high statistical learning abilities may be able to extrapolate from prototypical to nonprototypical patterns regardless of whether they have been exposed to nonprototypical items. Put simply, it may be possible for some L2 speakers to generalize from the prototypical double-object dative to the nonprototypical exemplars without any exposure, just as they could likely generalize from a prototypical transitive (*John hit the ball*) to a less prototypical transitive (*the ball hit the fence*) despite not having been exposed to the less prototypical exemplars.

Similar to Experiment 1, working memory was not related to the participants' performance on the dative test items, when contextual information provided through the discourse context was not sufficient for identifying the correct picture. The same null finding for working memory and test performance suggests that the learning task may not have been explicit enough to engage executive control functions of working memory (or may not have drawn extensively on its storage capacity). On the exit questionnaire, only five participants reported the double-object dative form when asked about the structure of the sentences they had heard, with only two of them specifying that inanimate nouns could occur in both the recipient and direct object positions. Based on the information provided by the participants, it does not appear that the majority of participants formed or were able to report any explicit knowledge about any patterns they had learned.

In contrast to Experiment 1, however, Experiment 2 revealed a significant correlation between working memory scores and performance on the exposure items. The dative exposure items contained multiple sentences and were much longer (21–28 words) than the Esperanto exposure items

TABLE 6
Summary of Regression Model for Datives

Predictor	*B*	*SE B*	*95% CI*	β	*t*	*p*	ΔR^2
Step 1: Dative exposure	.19	.11	−.04	.21	1.63	.109	.03
Step 2: Statistical learning	.24	.10	.05, .43	.32	2.48	.016	.07
Step 2: Working memory	−.05	.11	−.26, .17	−.06	−.42	.674	

(only three words), and required that participants access information across sentences. As a result, the task may have been sufficiently demanding that working memory capacity was engaged. However, what remains unclear is whether it was the length of the exposure items or the presence of novel nonprototypical exemplars that triggered the involvement of working memory. If working memory was engaged in the learning phase because of the length of the exposure items and the need to access information across sentences, then it should be implicated regardless of whether the exposure phase included nonprototypical exemplars. Furthermore, if statistical learning underlies pattern learning, then it should only predict test performance when the pattern to be learned has been presented. Therefore, the goal of Experiment 3 was to further clarify the contributions of statistical learning and working memory to L2 pattern learning by serving as a control for Experiment 2. The research question was:

RQ3. Do statistical learning and working memory predict L2 pattern learning in a familiar language without exposure to the new (nonprototypical) pattern?

EXPERIMENT 3

Participants

The participants were 35 L2 English speakers (21 women, 14 men) studying at the same university in northern Thailand as the participants in the previous experiments. They were first year students with a mean age of 18.6 years ($SD = .6$) and reported a mean of 13.7 years of prior English study ($SD = 2.3$) within Thailand. Only four participants had ever visited an English-speaking country, with stays ranging from 1 week to 3 months. In terms of their knowledge of additional languages besides Thai and English, five students reported having basic knowledge of Japanese (3) and Chinese (2). They were studying undergraduate degrees in engineering (17), business (16), and education (2).

Target Structure and Materials

As in Experiment 2, the target structure was the nonprototypical double-object dative construction, in which inanimate nouns occur as both the object and the recipient. The dative materials used in Experiment 2 were revised by replacing the six nonprototypical exposure items with prototypical double-object datives created from the same six verbs used for the other prototypical items (*sent, taught, showed, told, owed, offered*), which resulted in six sentences per verb. The new prototypical dative sentences were embedded in short discourse contexts to establish the recipient as given information, with the recipients expressed as pronouns and the objects as inanimate noun phrases. The six new exposure sentences were distributed across the four sets to direct participants' attention to different components of the two picture alternatives: environmental or contextual features (one item), different subjects (one item), different objects (two items), and different recipients (two items). Most importantly, the exposure phase did not include any nonprototypical datives. The participants could identify the correct pictures by relying on the animacy of the recipient and other contextual information in the sentences. Immediately following the exposure items, the test phase presented the same 12 nonprototypical test items used in Experiment 2. All exposure and test items were recorded by the same female L1 English speaker in Experiment 1, and presented aurally at the rate of 7 seconds per item using PowerPoint. Reliability of the dative items (Cronbach's α) was .75. The statistical learning and working memory tests were identical to those in the previous experiments. For Experiment 3, reliability was .63 for the statistical learning test and .85 for the working memory test.

Procedure and Analysis

The procedure and analysis were identical to those in Experiment 2, with the participants carrying out the working memory test (10 minutes), the statistical learning test (10 minutes), the

TABLE 7
Descriptive Statistics for Predictor and Outcome Variables

Variable	*M*	*SD*	95% *CI*
Statistical learning	8.91	2.94	7.90, 9.93
Working memory	4.31	3.22	3.21, 5.42
Dative exposure ($n = 24$)	21.26 (89%)	1.72	20.67, 21.85
Dative test ($n = 12$)	6.94 (58%)	1.45	6.44, 7.44

TABLE 8
Comparison of Scores in Experiments 2 and 3

Variable	*T*	*p*	Cohen's *d*
Statistical learning	−1.11	.269	.24
Working memory	−3.91	.001	.82
Dative exposure	0.14	.866	.03
Dative test	−2.43	.017	.54

dative tasks (20 minutes), and the exit questionnaire (10 minutes) during one regularly scheduled class. After completing the research tasks, for the remainder of the class (25 minutes) the participants carried out listening activities unrelated to the goals of the current study.

RESULTS

The participants' scores for the cognitive tests and for the dative exposure and test items are provided in Table 7. For the exposure phase, which contained all prototypical items, the participants' mean score was 21.26/24, or 89% accuracy. For the test phase, which included exclusively nonprototypical items that could not be identified by relying on animacy or contextual clues, their mean score was 6.94 out of 12, or 58% accuracy.

Compared to Experiment 2 (see Table 4), these participants had lower statistical learning and working memory scores, and scored lower on the nonprototypical dative test items despite having similar scores for the dative exposure items. As shown in Table 8, the differences in participants' working memory and dative test scores were statistically significant across Experiments 2 and 3. With respect to participants' performance on the dative test items specifically, the presence of the nonprototypical dative sentences during the exposure phase in Experiment 2 led to significantly higher test scores than the exposure to prototypical datives provided in Experiment 3.

TABLE 9
Dative Correlation Coefficients

Variable	2	3	4
1. Dative exposure	.21	−.02	−.16
2. Dative test	–	.05	−.14
3. Statistical learning		–	−.06
4. Working memory			–

Note. $^{*}p < .05$.

To address the research question, which asked whether statistical learning and working memory predict L2 pattern learning without exposure to the new pattern, correlations among the participants' statistical learning and working memory scores and performance on the dative exposure items were obtained. As shown in Table 9, there were no significant correlations among any of the predictor or outcome variables; therefore, no follow-up regression analyses were carried out.

To summarize the findings of Experiment 3, without any nonprototypical datives in the exposure phase, the participants' test scores were significantly lower than in Experiment 2. Thus, it does not appear that these L2 speakers could generalize from the more frequent prototypical sentences to the nonprototypical dative, without being exposed to exemplars of the target nonprototypical structure. None of the participants reported the double-object dative form in the exit questionnaires, either in its prototypical or nonprototypical form, which suggests that the exposure and test tasks did not facilitate the acquisition of any explicit knowledge that the participants were able to express. Unlike in the previous experiments, statistical learning was not associated with dative test performance. Exposure to the novel pattern may be necessary for L2 speakers not only to engage their statistical learning abilities but also to develop more abstract constructions that encompass both prototypical and nonprototypical exemplars. Unlike in Experiment 2, working memory was not correlated with performance on the dative exposure items in this experiment. The null finding for working memory suggests that it was the novelty of the nonprototypical dative sentences in Experiment 2 that may have engaged working memory, rather than the length of the exposure sentences.

GENERAL DISCUSSION

The current study examined the contributions of statistical learning and working memory to L2 speakers' ability to learn morphosyntactic patterns, as a way of explaining the general difficulty L2 speakers have with acquiring L2 constructions. One novel finding of this research was a significant association between L2 pattern learning and a measure of L2 speakers' statistical learning, based on an auditory task requiring the identification of nonadjacent dependencies. The positive relationship was consistent, in that it was obtained for Esperanto transitives and English datives. This finding highlights statistical learning ability as an individual difference variable moderating L2 speakers' success in morphosyntactic pattern learning, thereby extending previous research with L1 speakers (e.g., Gómez, 2002; Misyak & Christiansen, 2012) and recent studies with L2 speakers (Brooks & Kempe, 2013; Granena, 2013). With respect to the Esperanto transitives, as discussed previously, the key pattern pertains to thematic relationships (cued by accusative case morphology) between N_1 and N_2, which are separated by a verb, as in *cevalon pelas kato* (OVS, [cat chases horse]). For the nonprototypical English double-object datives, the key pattern is the thematic relationship between the verb and subsequent noun phrases. Based on association strength, contributions of statistical learning to Esperanto transitives (Experiment 1) and English datives (Experiment 2) appear to be roughly comparable, with about 12–26% of shared variance explained. Interestingly, statistical learning predicted only the test performance, when the crucial relationships among elements in the construction could not be identified through reliance on lexical knowledge or familiar cues such as word order (transitives) or animacy (datives). In essence, statistical learning was implicated only when novel to-be-learned information was included among the study materials. This suggests that statistical learning may be most relevant when understanding message content requires the identification of novel approaches to sentence interpretation.

The small yet significant contribution of statistical learning to L2 morphosyntactic pattern learning may at first sight seem rather trivial. However, this is clearly not the case, given that successful learning of nonadjacent, long-distance dependencies, compared to the learning of sequential regularities, is no simple task even for L1 adults (Newport & Aslin, 2004). One crucial requirement for successful nonadjacent statistical learning includes the presence of sufficient amounts of variability in input (Aslin & Newport, 2012; Romberg & Saffran, 2010). For example, L1 adults improve in their ability to detect nonadjacent regularities with an increasing amount of variability in the lexical content surrounding long-distance dependencies (Gómez, 2002; Gómez & Maye, 2005). In essence, heightened variability in training materials may serve as a perceptual cue for grouping the target regularities together or may highlight the target regularities against otherwise variable input backdrop. It is possible that the target materials in this study provided sufficient variability to engage statistical learning, at least for some speakers, with six nouns featured in Esperanto materials (Experiment 1) and six verbs with nonprototypical (inanimate) recipients included in dative materials (Experiment 2). The variability in dative materials in Experiment 2 was ostensibly even greater because all unique noun phrases were used in the roles of inanimate objects and recipients. Future research needs to investigate whether increasing amount of variability in input materials may result in greater involvement of statistical learning in L2 pattern learning. An overarching goal of such research would be to determine whether and to what degree statistical learning ability—as a potential mechanism for learning patterns and generalizing them to novel contexts (Aslin & Newport, 2012)—may explain construction learning.

With respect to working memory contributions to the learning of novel L2 morphosyntactic patterns, there was no association between a measure of L2 speakers' working memory (backward digit span) and their performance in tests that required morphosyntactic knowledge of the target patterns. However, in Experiment 2, there was a correlation between working memory and speakers' performance on the dative exposure phase, which presented both prototypical and nonprototypical items. Experiment 3 provided evidence that the engagement of working memory during the exposure phase in Experiment 2 can be attributed to the presence of both prototypical and nonprototypical items, as opposed to the greater length of the dative items, as compared to the Esperanto items in Experiment 1.

At first glance, these findings may seem at odds with prior research showing significant contributions of working memory to the processing and learning of L2 morphosyntax (e.g., Brooks et al., 2006; Coughlin & Tremblay, 2013; Kempe & Brooks, 2008). However, in the studies targeting the acquisition of morphosyntax, such as the gender and case system in Russian, working memory was only predictive of participants' performance on trained (old) lexical items, rather than on untrained materials, and the impact of working memory was restricted to the storage component of working memory, rather than to its processing (executive) function (Brooks et al., 2006; Kempe & Brooks, 2008). Similarly, in research focusing on on-line morphosyntactic processing, working memory capacity played a role only when processing costs were elevated, such as during integration of ambiguities in subject/object relative clauses (Havik et al., 2009; Roberts et al., 2007). In the current experiments, working memory was implicated in the participants' performance only for the dative exposure items in Experiment 2, where the presence of nonprototypical items may have increased processing demands. However, working memory capacity had no relationship to test performance for either morphosyntactic structure when test items presented the most novel language.

From a broader perspective, null effects of working memory L2 morphosyntactic pattern learning may be consistent with views of working memory as being mostly relevant to learning that involves an explicit, intentional component (Williams, 2012). For example, in a study targeting L1 English speakers' ability to categorize Russian gender nouns, the storage component of working memory predicted speakers' ability to memorize the association between gender categories and the nouns experienced during training, but had no impact on their ability to generalize the learned pattern to novel exemplars (Kempe, Brooks, & Kharkhurin, 2010). Similarly, in object categorization studies in the visual domain, working memory was positively linked only to participants' performance in rule-based conditions, where categorization decisions were driven by explicit hypothesis testing based on a verbalizable rule, but not in the information–integration conditions, where decisions were driven by procedural, implicit learning (DeCaro et al., 2009; DeCaro, Thomas, & Beilock, 2008; Tagarelli et al., 2011). The current results are in line with these findings, in that the learning involved in this study did not include a substantial explicit component, with the exposure tasks requiring speakers to assign appropriate argument roles by attending to utterance meaning. Furthermore, few participants expressed any explicit knowledge about the target patterns on exit questionnaires. In future research, it would be important to further investigate how working memory impacts L2 construction learning, targeting the types of learning that are strategic in nature, such as those that involve explicit teaching or that include deductive rule learning, as well as the learning situations that impose greater processing costs on speakers' cognitive capacity.

CONCLUSION

In conclusion, this study determined that statistical learning ability helps account for variation in L2 speakers' ability to learn morphosyntactic patterns. Future studies should test the effectiveness of enhancing the target language, such as by including greater variability in the stimuli or lengthening the exposure phase, in order to determine whether these techniques facilitate L2 learning. By testing a wider variety of target constructions, languages, and individual difference variables, future research should identify whether the effectiveness of pattern learning is affected by the construction to be acquired and its relationship to L2 speakers' previously known languages. For example, recent work by VanPatten and colleagues (2013) showed that the relationship between grammatical sensitivity and sentence interpretation was mediated by the specific structures in the languages, as well as the explicitness of instruction. It was beyond the scope of the current study to determine whether participants engaged in explicit or implicit/incidental learning during the exposure tasks, but future research should investigate the engagement of statistical learning and working memory during pattern learning under different levels of explicitness, perhaps by eliciting retrospective reports.

It seems likely that the engagement of different components of L2 speakers' aptitude during pattern learning is influenced by a wide range of factors, such as the nature of the task (form- vs. meaning-oriented), the provision or absence of explicit grammatical information, and the length of the exposure phase. The current experiments provided short exposure phases (10 minutes), so it is not clear whether the results would be similar for longer training periods. Particularly for constructions in which long-distance dependencies are crucial for establishing correct form–meaning mappings and in contexts where explicit grammatical information is not provided, statistical learning may help account for variation in L2 speakers' performance. By exploring these issues in future research, it will be possible to clarify the conditions under which L2 learners are successful at pattern learning.

NOTE

[1] Working memory was correlated with the participants' performance for both the prototypical items ($r = .40$, $p = .002$) and the nonprototypical items ($r = .34$, $p = .009$).

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APPENDIX A

Esperanto Items: Exposure Phase

	SVO Sentences			OVS Sentences		
Set 1: Pictures had completely different nouns	kapro batas tauron	cevalo pelas katon	kato pelas kapron	pilkon pelas tauro	makropon batas kato	cevalon batas pilko
Set 2: Pictures had the same nouns, but different verbs	kato pelas cevalon	makropo pelas tauron	pilko batas markropon	katon batas makropo	kapron pelas tauro	pilkon batas cevalo
Set 3: Pictures had the same verb and object, but different subjects	cevalo batas kapron	makropo pelas kapron	tauro batas pilkon	tauron batas cevalo	cevalon pelas tauro	katon pelas kapro
Set 4: Pictures had the same subjects and verbs, but different objects	kapro pelas pilkon	makropo pelas katon	pilko batas katon	cevalon batas kapro	kapron batas pilko	makropon pelas kapro

Esperanto Items: Test Phase

Pictures for each item were images of reversible events (e.g., horse chasing goat paired with goat chasing horse).

SVO Sentences	OVS Sentences
tauro batas kapron	makropon batas tauro
kapro batas pilkon	cevalon pelas pilko
pilko batas tauron	pilkon pelas kato
makropo batas cevalon	tauron pelas makropo
kato pelas makropon	katon batas cevalo
cevalo pelas makropon	tauron pelas kato

APPENDIX B

Dative exposure items (Experiment 2)

Set 1: Pictures had different contextual details	Set 2: Pictures had different subjects	Set 3: Pictures had different objects	Set 4: Pictures had different recipients
This summer Shelly had to stay home while her brother Ted got to go to New York. She missed him a lot. So Ted sent her a postcard.	Last week Stan lost his favorite toy. He was upset and called his grandfather, who wanted him to feel better. So his grandfather sent him a comic book.	Every day after school Kevin rides his bike to see his sister Betsy. One day he broke his bike. So Betsy offered him an ice cream cone.	Sandy is a famous cookbook writer. She's doing a new book and asked for suggestions. So many fans sent her recipes.
John enjoys spending time at the beach with his grandmother. She knows a lot of fun activities. So she taught him a game.	Sally's favorite dessert is chocolate cake. But it never tastes good when she makes it. So her mother taught her the recipe.	Josie was worried about her grades. Her tutor said she had problems with modern languages. So he taught her some grammar.	Mr. Smith enjoyed teaching students about chemistry. But they had a lot of problems with the last exam. So he told them the answers.
Grace and Bob wanted to go to Hawaii. Bob had to work so he asked Grace to take a camera. So she showed him the photos.	Bob's new dog chewed on everything. One day he forgot to close the closet door. When his wife got home from work, Bob showed her the mess.	Andy was moving to Chicago for work. He asked a realtor to help him find a place to live. So she showed him a house.	Billy spends his weekly allowance in Mrs. Johnson's candy store. Last week he forgot his money, but took some candy. So Billy owed her 5 dollars.
Mrs. Jones leads an art class every week. This week she introduced photography. But her students couldn't take good photos, so she told them the rules.	Every year Dick and Jane meet at a business conference. Last year Jane forgot her wallet at happy hour. So she owed him a drink.	Every day Marcy got coffee at Starbucks. This morning she was in a rush and spilled her coffee on a man. So Marcy owed him a new shirt.	Every day Maggie takes the bus to school and it's really crowded. This morning an old man got on the bus. So Maggie offered him a seat.
Jane plays at her aunt's house after school every day. Today Jane accidentally broke her aunt's favourite flower pot. So Jane owed her an apology.	Johnny played on his school baseball team. Today he couldn't play because he forgot part of his uniform. So the coach offered him a hat.	Susie spends every morning watering her garden. One day she found that all her plants had been stolen, so she painted the garden a sign.	Greg's apartment was really messy. He got some baskets to help organize his stuff. So when he was cleaning up, he shot the basket his keys.
John borrowed Grace's truck to go mountain biking for the weekend. When he returned it, Grace found a big scratch on the door, so she brought the truck some paint.	John enjoys gardening. One day he noticed that his favorite tree looked sick, so he fixed the tree some fertilizer.	Johnny had a bouquet of flowers for his wife. When he got home, he noticed the living room vase was empty, so he saved the vase a rose.	Ted was at a model train show when the engine of his model broke. He had an extra one at home. So he called his wife and she shipped the train an engine.

Dative test items (Experiments 2 and 3)

Pictures for each item were images of reversible events (e.g., frying eggs for a steak, or frying a steak for some eggs).

1. Every weekend Steve's girlfriend complained about the holes and stains on his chair. So he threw the chair a pillow.
2. John's children broke a table while they were playing. It was his favorite table. So John built the table a leg.
3. Joan's daughter loves Disney cartoons on her birthday cake. But the cake Joan bought was boring. So Joan baked the cake a Mickey Mouse.
4. Peter's mother was a terrible cook, but she liked to barbecue steak. She made a steak for his dinner. So he cooked the steak a sauce.
5. Mary's children hate eggs, but that's what their father made this morning. The children were unhappy. So she fried the eggs some ham.
6. Irene's daughter thought her new dress was boring. Irene couldn't afford another one. So she cut the dress some ribbons.
7. Nick's son was an artist who made murals. He had an accident and couldn't finish his last mural. So Nick wrote the mural a title.
8. Susie's daughter spilled milk all over the dolls in her toy box. Because of the milk, their clothes were ruined. So Susie promised the dolls new dresses.
9. Bill's dog destroyed his living room while he was out of town. The dog broke his favorite lamp. So Bill mailed his lamp a shade.
10. Sharon's daughter loved to decorate her smart phone. But Sharon couldn't afford new accessories. So she traded the phone a new case.
11. Mike's wife prepared her presentation on his computer. But she forgot to upload the images. So Mike fed his computer the pictures.
12. Ruth worked in an office with slow computers. Her internet connection was always down, and she couldn't finish her work on time. So Ruth served the network a warning.