How Selective Are 3-Year-Olds in Imitating Novel Linguistic Material?

Colin Bannard and Jörn Klinger
University of Texas at Austin

In 3 studies we explored when 3-year-olds would imitate novel words in utterances produced by adult speakers. Child and experimenter took turns in requesting objects from a game master. The experimenter always went first and always preceded the object’s familiar name with a novel adjective (e.g., “the dilsige duck”). In the first 2 experiments, we found that children were more likely to reproduce the adjective when there were 2 different instances of the same object present in the situation than when there was only 1 or when there were 2 objects of different types present. Thus, children seemed to be sensitive to the descriptive and contrastive function of the adjectives in determining which parts of the utterances to reproduce. Nonetheless, replication of even redundant material was over 50%, suggesting a strategy of somewhat blind copying. In the 3rd experiment, we found that children were less likely to reproduce a redundant adjective when the speaker indicated gesturally that he did not intend to produce it than when he clearly produced it intentionally. We distinguish insightful imitation (the copying of a speaker’s goal and means when motivated by insight into why those particular means were chosen) and blind imitation (the copying of a speaker’s goal and means with no awareness of why those specific means were chosen) from mimicry. We explore the roles that these modes of imitation might play in language development.

Keywords: first language acquisition, imitation, social cognition

While debate continues as to the role biology plays in determining children’s knowledge of their native language, it is not disputed that languages are at least partially culturally transmitted. Languages are sets of for the most part arbitrary conventions, and as such, whatever predispositions might be involved, the only way that children can learn them is by doing as others do. Given this, one might expect imitation, as a core mechanism of cultural transmission (Boyd, Richerson, & Henrich, 2011; Tomasello, Kruger, & Ratner, 1993), to be an important concept in the study of language development. However, while imitation is central to the study of human development in other areas, from the acquisition of basic (Meltzoff & Moore, 1977) to more complex (Meltzoff, 1995) and even hierarchical (Flynn & Whiten, 2008; Whiten, Flynn, Brown, & Lee, 2006) skills, discussion of imitation (e.g., what forms it might take, what mechanisms might support it) is notably absent from contemporary debates about language development.

In many respects this situation is understandable. Languages are combinatorial systems, not inflexible procedures. While acquisition might begin with the rote learning of phrases and word sequences (Bannard & Matthews, 2008; Clark, 1974; Peters, 1983; Tomasello, 2003), in order to communicate their emerging needs, interests, and perspectives, children will need to learn how to recombine known elements (morphemes and words) in producing novel words and utterances that they have not heard before. Simple direct copying will thus not get them far. Furthermore, the speech signal contains a great deal that children will not want to reproduce (e.g., errors, context-specific pauses). To learn something as complex and structured as a language, children must understand what another’s utterance was intended to communicate and which aspects of the utterance did what. And yet imitation is frequently invoked in explaining the acquisition of complex skills in other domains (Flynn & Whiten, 2008; Whiten et al., 2006). In order to learn even something as simple as using silverware through imitation, children must understand the function of the various parts of the observed act (Saylor, Baldwin, Baird, & LaBounty, 2007). And crucially, all actions they need to learn are not clearly demarcated but rather are caught up in the passage of everyday life and are performed by human agents who make all sorts of errors in their performance (from tripping while climbing steps and dropping keys while opening doors to the more serious errors revealed in emergency room statistics). Previous work on nonlinguistic imitation has looked at how children are able to determine and filter out accidental subcomponents of action sequences that they are learning by imitation (Carpenter, Akhtar, & Tomasello, 1998).

A part of the problem in discussing imitation in language learning is that in regular parlance the term “imitation” is too broad—it covers all situations in which one person reproduces the behavior of another. In exploring the diverse range of such imita-
tive behaviors seen in nonhuman species, animal cognition researchers have come up with a number of detailed distinctions (for a summary written for developmental psychologists, see Want & Harris, 2002). The aim of this article is to look at what is involved in children’s duplication of other speakers’ productions, and in order to accomplish this one must similarly take a more nuanced perspective on the reproduction of others’ behaviors and adopt some additional terminology.

One distinction that is made in the animal literature is that between mimicry and other forms of reproduction. Mimicry ( Tomasello et al., 1993) is said to occur when one organism reproduces the surface form of another’s behavior without attending to why the behavior was produced. In a language acquisition context this might be said to have occurred when children repeat what an adult has said with no communicative goal and no insight into what the utterance might have meant for the adult. While discussion of imitation in the language-learning literature has tended to focus on exactly this kind of rote repetition (e.g., Snow, 1981), the term “mimicry” was introduced in the animal learning literature in order to distinguish such cases from real imitation. This distinction is important in discussing language learning, because although rote repetition may have a role to play in phonological and lexical development, it has clearly limited value when it comes to learning about multiword speech. We adopt the distinction in this article.

The term “imitation” is reserved for situations in which the producer of an action is aware of its original producer’s goal. However, within this category of imitation it is necessary to make a further distinction. The minimal requirement for distinguishing imitation from mimicry is that the actors reproduce the observed behavior and the goal toward which it was performed. It is not necessary that they be aware of why the specific actions or forms were chosen. As Want and Harris (2002) pointed out, “an imitator might replicate both the form and the goal of an observed behavior but fail to understand the affordance of the objects involved in that behavior or the link between the actions and the goal they subserve, in effect becoming a blind imitator” (p. 3). To put it another way, while one can distinguish three components in human actions—the goal, the means, and the mapping between goal and means—imitation requires awareness of only the first two. Following Want and Harris, we refer to imitation that involves all three elements as “insightful imitation” and imitation that involves only the first two as “blind imitation.”

The goal of the experiments described in this article is to explore the roles that blind imitation and insightful imitation (as distinct from mimicry) play in the learning of multiword speech and where possible to distinguish between them. We investigated how children decide when they should reproduce unfamiliar linguistic material produced by an adult speaker. In the first pair of studies, we asked whether children would more often reproduce a nonce adjective in the speech stream if there were a functional reason for its being there (as opposed to not). In the third study, the speaker marked his use of a nonce adjective as either accidental (a slip of the tongue) or intentional.

**Experiment 1**

In the first study, we examined whether children consider the informational needs of their interlocutor in determining whether to reproduce a novel adjective used by an adult speaker. We devised a game in which the child and another player (E1) were required to request a series of objects from a game master (E2). E2 would hold up an object or pair of objects, and E1 would request one and receive it. The objective for the child was then to obtain the same object as did E1. When making a request, E1 would always precede the real name of the object with an adjective-like novel word. In a *choice* condition, two instances of an everyday object (one bearing modifications) were presented, and upon request E1 was handed the modified one, while in the other (the *single-object* condition) only a single object was presented. Both conditions were repeated four times, with the order counterbalanced. In the single-object condition, the adjective was redundant, while in the choice condition, an adjective could help the game master to determine which of the two objects was being referred to. We were interested in when the child would copy the adjective.

**Method**

**Participants.** Sixteen normally developing, monolingual, German-speaking children were included in the study (5 boys, 11 girls). They were 3 years old (range = 3 years 2 months to 3 years 6 months; mean age = 3 years 5 months). Three additional children were tested but not included due to fussiness. The children were recruited and tested at day-care centers in a medium-sized German city. No information was collected concerning the socio-economic status of the individual participants’ families. The children at all day-care centers were predominantly White and middle-class. Parental consent was obtained in all cases.

**Materials and design.** We used eight different items—such as a plastic flower, a rubber duck, and a spoon—that we expected would be familiar to German 3-year-olds. Each item was presented in both a plain and a modified version. The modifications were designed so as to make it hard to describe them with a single German adjective. For example, the modified version of the spoon had cloth-covered, wormlike wires pasted on it. Details of all toys and German nouns used can be found in the *Appendix*.

Our novel words were all two syllables long, ended in “ig” (following the prototypical form for German adjectives, e.g., “dil-sig,” “impig”), and occurred before the noun (where adjectives would occur in German). The toys were always presented in the same order, with order of condition and use of adjective across condition fully counterbalanced. In the warm-up we used additional items: a picture book containing images of the unmodified experimental items, three single items, four sets of paired items with one distinguishing feature, and two single modified items. Details of all adjectives can be found in the *Appendix*.

**Procedure.** E1 and the child sat opposite E2, with a table between them. The experimenters played a game with the child in which E1 was a coparticipant and E2 was a game master. The game required the child and E1 to request items from E2. The goal of the game for the child was to collect the same items as E1. If both E1 and the child got the same item, they were allowed to put them into a treasure chest. The child’s turn was always after E1’s, such that in order to receive the same object the child would have to selectively imitate E1’s utterance.

**Warm-up.** To familiarize children with the game, the experiment was preceded by a sequence of warm-up trials in which they were tested individually. First E1 showed children pictures of the objects used in the experiment and had them name them.
the rare case that children failed to promptly produce a label for the picture, E1 identified it for them and then asked them again to name it. For one of the objects, a shovel, there were two frequently used labels in German. While most of the children used the label “Schaufel,” four referred to it as “Schippe.” For those who chose this label in the warm-up, E1 adopted that label for the test phase.

E1 next explained how the treasure chest worked: that there were two compartments, one for the child and one for E1 and that the chest could be opened only when E1 and the child had matching items. E2 then presented a series of three single familiar items and explained/demonstrated the rules of the game. Next E2 presented four pairs of objects (big/small ball, big/small thread, red/blue brick, dark/light ape) that required the use of an adjective to differentiate them. E1 requested and was given “the small ball,” “the small thread,” “the blue brick,” and “the light ape” (thereby demonstrating the contrastive function of adjectives to the child). Between the presenting and requesting of each of these objects by E1, children would be asked to make a request. If they picked a different object from that picked by the experimenter in any of the trials, E1 would praise them for asking but also lament that they did not have the same items and therefore could not put them into the treasure chest. E1 would suggest that those children ask E2 for the correct item, so that in the end they could both have the same item. If the children asked for the correct item immediately, E1 praised them and commented on how lucky they were that the children had not picked the other object, as then they would not have been able to put it into the box.

Finally there were two more warm-up trials with one modified item at a time (a flute with pieces of foil attached; a horse with pieces of a blue card attached). When asking for the objects, E1 used novel adjectives and upon receiving the items pointed to their pieces of a blue card attached). For those who chose the object received were contingent on children’s speech, then they might learn this contingency, allowing them to produce context/condition-appropriate responses in the absence of any understanding of the function of the adjective and leading to our finding a misleading effect of condition). Once the children and E1 both had the same object, the two of them could put their objects in the treasure chest. If children didn’t ask for an object, E1 encouraged them to speak (e.g., saying “What do you want?” or “Just ask”). If children still did not ask, E2 also said, “You can just ask me for it.” When children did not request the object in the first experimental trial, we repeated the trial to make sure they understood the game. This repeated trial was excluded for coding purposes. None of the subsequent trials were repeated.

Each child went through eight trials, alternating between choice and single-object conditions. Items always occurred in the same order and were arranged in sets of two. Two novel adjectives belonged to each set and were fully counterbalanced across items within sets. The two conditions were also fully counterbalanced across items within sets.

Coding. In our coding we distinguished between three types of response: reproduction of the novel adjective, production of a bare noun, and production of a familiar word prior to the noun. If children produced the novel adjective or attempted to do so (i.e., they produced a form phonologically similar to it such as “impi” for “impig”), this was counted as “replication.” If they did not produce any phonological information before the object-name, this was coded as “bare noun.” In a few special cases, children produced a familiar adjective unrelated to the phonological form of the novel one (e.g., “Gib mir mal die blaue Ente”/”Give me the blue duck,” where “blau/blue” in no way resembled the novel adjective “impig”). This was coded as “other linguistic material.”

When children avoided choosing to reproduce the correct adjective by instead choosing a different mode of request (e.g., by saying “I want a duck like that too” or by pointing), the trial was treated as missing data. One trial was missed due to experimenter error. These criteria gave a total of eight missing data points out of a total of 128 trials. Data for a randomly chosen 25% of trials was further coded by another research assistant, who had only the audio tracks of the recordings and was thus blind to condition. Agreement between coders was 96.88% (κ = 0.926).

Analysis. As the children produced three different responses (replication, bare noun, or other material), we analyzed the data using a variety of multinomial regression models (Long, 1997). As each child participated in multiple trials, we used a multilevel version in which participant was included as a random effect on the intercepts. The reported models were fitted using the HLM6 software (Raudenbush, Bryk, Cheong, & Congdon, 2004). In multinomial regression, we assigned one outcome to be the “reference” outcome and then estimated how the different predictors affected the probability of seeing the other outcomes relative to this reference (it can thus be interpreted in the same way that one would interpret multiple binary logistic regressions). We chose the reference to be the production of a bare noun. The table thus contained an intercept for each of the other responses (the estimates of the model are the log-transformed odds ratios, so that no preference for a given response over the bare noun response in the single-object condition would result in an estimate close to zero for that response’s intercept) and estimates of how a trial’s being in the choice condition (coded as 1) rather than the single-object condition (coded as 0) and the position of that trial in the session affected the probability of seeing that outcome. Trial number was grand mean–centered.

The variance attributable to differences between participants (rather than to any aspect of the procedure; this is equivalent to the between-subjects variance component in a repeated measures analysis of variance) was evaluated using a χ² test. A t test was used to evaluate the statistical significance of each predictor’s effect on the outcome. The log odds ratio provides a measure of the practical
Results

The children’s responses are summarized in Figure 1. This stacked area chart shows the proportion of children who produced a given response for each of the four trials conducted in each condition (as noted above, the conditions were alternated, with the condition that came first being counterbalanced across children). As is conventional, these proportions are over only those cases in which children produced a response. In line with our prediction, children imitated the novel adjectives more often in the choice than in the single-object condition. This difference is consistent across trials, with the proportion of replication responses appearing to increase in both conditions. However, the children showed a consistently high rate of replication even in the single-object condition. This difference was found to be significant in our multinomial model of imitation (as noted above, the conditions were alternated, with the condition that came first being counterbalanced across children).

Where participant means are reported, confidence intervals (CIs) are provided based on a percentile-method bootstrap procedure (see e.g., Chernick, 2008) in which responses were sampled with replacement at the participant level and then at the group level for each of 10,000 iterations.

Discussion of Experiment 1

Our analysis indicates that children reproduced a novel word significantly more often when two objects were presented rather than a single object. In a total of 10 cases (out of 128 total trials), the children produced material other than the novel adjective that was modeled for them. All 10 were existing German adjectives/attributives. The 10 cases accounted for 12% of the responses in the children produced material other than the novel adjective that was modeled for them. All 10 were existing German adjectives/attributives. The 10 cases accounted for 12% of the responses in the choice condition as opposed to 5% in the single-object condition. This difference was found to be significant in our multinomial regression model. Seven out of 10 usages accurately referred to properties of the objects presented. Four of these seven were also pragmatically fitting, in that they distinguished between the two objects presented.

Our analysis allows us to conclude that the children were influenced by the context in structuring their requests. Their replication of the novel linguistic material seems to depend on their understanding of its function and is not mere mimicry. But what is it about the choice condition that results in them replicating the adjective with greater frequency? One possibility is that they are sensitive to the contrastive function of the adjective (what
Summary of Fixed Effects for Multilevel Multinomial Regression Analysis for Experiment 1

<table>
<thead>
<tr>
<th>HPD intervals</th>
<th>Estimate</th>
<th>Lower</th>
<th>Upper</th>
<th>SE</th>
<th>T ratio</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>Intercept</td>
<td>−0.069</td>
<td>−4.880</td>
<td>5.585</td>
<td>0.949</td>
<td>−0.072</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Condition</td>
<td>2.264</td>
<td>1.399</td>
<td>6.121</td>
<td>0.743</td>
<td>3.045</td>
<td>114</td>
</tr>
<tr>
<td></td>
<td>Trial number</td>
<td>0.373</td>
<td>0.141</td>
<td>1.185</td>
<td>0.167</td>
<td>2.228</td>
<td>114</td>
</tr>
<tr>
<td>Other linguistic material</td>
<td>Intercept</td>
<td>−4.404</td>
<td>−19.575</td>
<td>−3.349</td>
<td>1.356</td>
<td>−3.248</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Condition</td>
<td>2.462</td>
<td>0.222</td>
<td>9.758</td>
<td>1.242</td>
<td>1.982</td>
<td>114</td>
</tr>
<tr>
<td></td>
<td>Trial number</td>
<td>−0.217</td>
<td>−1.162</td>
<td>0.229</td>
<td>0.247</td>
<td>−0.880</td>
<td>114</td>
</tr>
</tbody>
</table>

Note. The single-object condition is coded as 0; the choice condition is coded as 1. HPD = 95% higher posterior density.

Karmiloff-Smith, 1979, calls the determiner function—that given the presence of two objects, the adjective is necessary in order to allow the hearer to disambiguate. However, there is another difference between the conditions. In the single-object condition, only one familiar, unmodified object was presented, while in the choice condition there was an object with modifications. An alternative explanation, then, is that the children were simply responding to the modifications and applying a simpler heuristic that such a modification requires an adjective (picking up on the descriptive function—or in the terms of Karmiloff-Smith, 1979, the descriptor function—rather than the contrastive function of the adjective). If this were the case, one might predict that the children would produce the adjective in response to the modifications even if the modified object occurred alone. We set out to address this concern by conducting a second experiment, in which a modified object occurred in both conditions.

Experiment 2

The game played in this experiment was similar to that played in Experiment 1. The procedure for one condition (here referred to as the same-category condition) was identical to what we called the choice condition in Experiment 1. However, in the other condition, rather than holding up a single unmodified object, the game master held up two objects, one a modified object (as used in the choice condition) and the other a different familiar object. This condition is referred to as the different-categories condition. As in Experiment 1, the difference between the two conditions was that in one condition (the same-category condition) the novel adjective was necessary to uniquely distinguish the target object, while in the other condition (the different-categories condition) it was redundant, this time because the target object was distinguishable from the paired object on the basis of the noun alone. Unlike in Experiment 1, however, the target object was modified in both conditions, meaning that children could determine the adjective to be more applicable in the same-category condition only based on its contrastive function (the contrast between the two objects) and not simply from the perceptual attributes of a single object.

Method

Participants. Twenty-eight normally developing, monolingual, German-speaking children were included in the study (14 boys, 14 girls). They were 3 years old (range = 3 years 2 months to 3 years 6 months; mean age = 3 years 4 months). Three additional children were tested but not included: 1 due to fussiness, 1 due to experimenter error, and 1 due to a failure to follow the rules of the game (asking for the different-category object in the different-categories condition on more than one trial). The children were recruited and tested at day-care centers in a medium-sized German city. No information was collected concerning the socioeconomic status of the individual participants’ families. The children at all day-care centers were predominantly White and middle-class. Parental consent was obtained in all cases.

Materials and design. We used the same eight target objects and the same eight novel words as in the first experiment. We also used four new familiar objects (the distractor objects occurred in only four out of the eight trials for any given child). Details are given in the Appendix.

Procedure. The procedure for the warm-up and test were the same as in Experiment 1 except that instead of a single-object condition we had a different-categories condition, in which E2 presented a modified object and a plain object of a different category. As in Experiment 1, when a participant used a plausible alternative term to refer to one of the familiar objects during the picture-naming phase, we adopted that term for the child in the main experiment. In this experiment, one of the participants referred to the glasses (“brille”) as sunglasses (“sonnenbrille”), and this term was adopted in the main section of the study.

Coding. The coding scheme was the same as that used in Experiment 1. One data point was excluded due to experimenter error, giving a total of one missing data point out of 224 data points. Data for a randomly chosen 32% of trials was further coded by a research assistant who had only the audio tracks of the recordings and was thus blind to condition. Agreement between coders was 95.83% (κ = 0.85).

Analysis. We analyzed our data using the same procedures as for Experiment 1. The different-categories condition was coded as 0, and the same-category condition was coded as 1.

Results

The children’s responses are summarized in Figure 2. This stacked area chart shows the proportion of children who produced each response for each of the trials conducted in each condition (as in Experiment 1, the conditions were alternated, with the condition that came first being counterbalanced across children). As in Experiment 1, children replicated the novel adjectives more in the
choice condition (here referred to as the same category) than in the other condition (here the different-categories condition). The rate of replication increased over the trials in both conditions. However, the children showed a consistently high rate of replication even in the different-categories condition (participant $M = 0.651$, 95% CI [0.491, 0.804]).

The fixed effects from our multinomial regression analysis are summarized in Table 2. The model tells us that the participants were significantly more likely to prefer replication in the same-category condition (coded as 1) than in the different-categories condition (coded as 0). The effect size for this was substantially smaller than in Experiment 1 (an odds ratio of 2.66 compared with 9.62). They were also significantly more likely to prefer a replication of E1’s production in later than in earlier trials, a pattern that has a similar effect size to that found in Experiment 1 (the odds ratios being 1.45 for Experiment 1 and 1.27 for Experiment 2). Participants were significantly more likely to prefer the “other material” response in the choice than in the single-object condition, although the effect size is much less than in Experiment 1 (an odds ratio of 4.01 compared to 11.73). As in Experiment 1, trial number seems to have had no effect on the production of other linguistic material. The estimated log odds ratio for the replication response intercept was marginally significantly greater than 0 (the ratio of the probability of replication to the probability of producing a bare noun was greater than 1), indicating a preference for replicating the novel adjective over producing a bare noun in the different-categories condition. This confirms that a high rate of replication was seen for even the condition that has (out of the two conditions) the lower proportion of replication. The HPD ranges observed for each of the parameters confirm the robustness of our reported effects.

As both condition and trial number were again found to affect the probability of children’s replicating E1’s novel adjective, we next looked at whether there was any interaction between these predictors for this response. We found that adding an interaction between condition and trial number did not improve the fit of the model (it led to no change in deviance, so no formal test is reported).

The variance attributed to differences between participants (rather than to any aspect of the procedure; this is equivalent to the between-subjects variance component in a repeated measures analysis of variance) was significantly greater than 0 for replication, $\chi^2(27) = 124.42, p < .001, \varphi = 0.40$, but not for the use of other linguistic material, $\chi^2(27) = 36.09, p = .113, \varphi = 0.21$.

**Discussion of Experiment 2**

The pattern of results observed here appears to confirm that the children were affected by the informational requirements of the context (the contrastive function of the adjective) in deciding whether to reproduce novel linguistic material. The difference between conditions was much reduced from that seen in Experiment 1, and the effect size was consequently much smaller. The presence of a higher rate of replication in the different-categories condition in Experiment 2 than in the single-object condition in Experiment 1 suggests that between-conditions variation in the perceptual qualities of the object was having an effect—that the fact that the object was modified in the choice condition and not in

<table>
<thead>
<tr>
<th>Condition</th>
<th>Estimate</th>
<th>Lower</th>
<th>Upper</th>
<th>SE</th>
<th>T ratio</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication Intercept</td>
<td>1.186</td>
<td>0.053</td>
<td>4.554</td>
<td>0.603</td>
<td>1.969</td>
<td>27</td>
<td>0.059</td>
</tr>
<tr>
<td>Replication Condition</td>
<td>0.979</td>
<td>0.193</td>
<td>2.594</td>
<td>0.477</td>
<td>2.055</td>
<td>217</td>
<td>0.041</td>
</tr>
<tr>
<td>Replication Trial number</td>
<td>0.242</td>
<td>0.082</td>
<td>0.606</td>
<td>0.103</td>
<td>2.341</td>
<td>217</td>
<td>0.020</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition</th>
<th>Estimate</th>
<th>Lower</th>
<th>Upper</th>
<th>SE</th>
<th>T ratio</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other linguistic material Intercept</td>
<td>−1.531</td>
<td>−3.890</td>
<td>0.761</td>
<td>0.659</td>
<td>−2.323</td>
<td>27</td>
<td>0.028</td>
</tr>
<tr>
<td>Other linguistic material Condition</td>
<td>1.388</td>
<td>0.188</td>
<td>3.440</td>
<td>0.690</td>
<td>2.011</td>
<td>217</td>
<td>0.045</td>
</tr>
<tr>
<td>Other linguistic material Trial number</td>
<td>0.147</td>
<td>−0.134</td>
<td>0.556</td>
<td>0.148</td>
<td>0.999</td>
<td>217</td>
<td>0.319</td>
</tr>
</tbody>
</table>

**Note.** The different-categories condition is coded as 0; the same-category condition is coded as 1. HPD = 95% higher posterior density.
the single-object condition may have been causing participants to reproduce the adjective more in the choice condition and not purely the presence of a contrasting object. However, it is clear from Experiment 2 that that difference between conditions cannot account for all of the observed effect.

To summarize so far, then, Experiments 1 and 2 found that children were more likely to replicate novel linguistic material when that material was necessary in order to disambiguate which of a pair of objects was being referred to—they seemed to be sensitive to the contrastive effects of adjectives. The higher rate of imitation in the different-categories condition relative to the single-object condition and the substantially greater effect size together suggest that children are also sensitive to the descriptive function of adjectives. The descriptive function of adjectives is a response to the perceptual properties of a single object, while use of the contrastive function requires an understanding of the larger context (the target object’s similarity to or difference from other objects present). The descriptive function has been argued (Karmiloff-Smith, 1979) to precede the contrastive function, and one might characterize the former as semantic and the latter as pragmatic. It is therefore interesting that both seem to play a role in children’s decisions about whether to reproduce the adjective.

Relating this back to our discussion of the different mechanisms involved in the reproduction of cultural forms, these results tell us that children’s reproduction of others’ speech involves more than simple mimicry. However, it is also interesting that children replicated the novel adjective in almost 50% of cases in the single-object condition in Experiment 1 and in over 60% of cases in the different-categories condition in Experiment 2. It seems that children are able to use the communicative ends of speakers, rather than just their means, when choosing whether to replicate but that taken as a group they still display a clear tendency to replicate the means even when the situation does not require it. While the increased rate of imitation in the different-categories condition in Experiment 2 (relative to the single-object condition in Experiment 1) might be attributed to the inclusion of an object that was modified (and thus was perceptually consistent with the inclusion of an adjective, even if one was not pragmatically essential), there was no contextual justification for its inclusion in the single-object condition in Experiment 1 (where the object bore no modifications), and so the rate cannot be fully attributed to this. It is possible that the children in Experiment 1 were aware of the descriptive function of adjectives and that they were attempting to replicate this function in the single-object condition. However, it is also clear that they had no feature onto which to map the adjective and that their imitation of the adjective was somewhat “blind.”

An interesting finding in this context is the effect of trial number on the rate of replication. One might predict an increase in replication in the choice condition as children come to better understand the task of distinguishing between the two objects. However, while we did find a marginally significant effect of trial number, we also crucially found that the addition of an interaction between condition and trial number did not significantly improve the fit of a logistic regression model, suggesting that any effect of trial number applied across both conditions. One explanation for this is that the adults’ repeated use of an adjective reinforces that it is intentional. Adults might produce a redundant adjective once as an oversight. However, when they repeat this multiple times, it seems reasonable to assume that they have a clear motivation for doing so. Such an assumption would follow from an expectation that adults are rational and that any linguistic material repeatedly introduced was done because it was an efficient means to achieve their goal. In a study by Gergely, Bekkering, and Király (2002), 14-month-old children appeared to make such an inference in selecting when to imitate a functionally opaque aspect of a non-linguistic act. The high rate of replication in the different-categories condition prior to any effect of trial number suggests that children are often willing to follow an adult model in producing a novel adjective even in the absence of a contextual purpose. It would appear to make sense, then, that having adults produce such an adjective repeatedly should reinforce the impression that their use was intentional and thus increase the tendency of children to follow.

If this analysis is correct, then children do seem to engage in blind imitation—the copying of the means by which adult speakers achieved a particular goal in order to achieve the same goal, while also being blind to how the means maps onto and facilitates the goal. However, before accepting this we must accept another possible alternative—that this “blind imitation” is pure mimicry in a subset of the participants and that while some participants are affected by context others are simply replicating the form without any concern for the speaker’s goal. This is at least plausible given the pattern of data that we saw—out of the 16 participants in Experiment 1 (where we had the strongest evidence of redundant imitation, since in the single-object condition the adjective played no descriptive or contrastive role), 6 children produced an adjective in all trials, 1 child never produced an adjective, and 4 children produced an adjective only in the choice condition (with 2 of these children doing so in all choice trials). Our goal in Experiment 3 was to explore whether children’s apparently blind reproduction of the redundant adjectives is sensitive to the goals of the speaker. We did this by contrasting a condition in which the adjective was redundant with one in which it was similarly redundant but in which it was marked as unintentional (following a similar design used to look at action imitation by Carpenter et al., 1998). In other words, in order to explore whether children’s perception of the adjective as intentional and goal-oriented is important to their reproduction of it, we looked at whether they would be less likely to reproduce it when that intention was drawn into question.

**Experiment 3**

The unintentional-speech situation that we explored in Experiment 3 was the slip-of-the-tongue. We set up an imitation game similar to that in Experiments 1 and 2, in which E1 asked E2 for objects, adding a novel word in the request. Our control condition was the same as the single-object condition in Experiment 1, with E1 requesting a single object using a novel adjective and noun and the child then having to request the same object. There was also a single object in our experimental condition, but immediately after producing the adjective to request it, E1 would indicate it was produced in error (this condition is hereafter referred to as the **accidental** condition). We hypothesized that children would imitate the novel word less in the accidental than in the control condition.
Method

Participants. Sixteen normally developing, monolingual, German-speaking children (none of whom had participated in Experiments 1 or 2) were included in the study (11 boys, 5 girls). They were 3 years old (range = 3 years 2 months to 3 years 6 months; mean age = 3 years 4 months). Five additional children were tested but not included due to fussiness. The children were recruited and tested at day-care centers in a medium-sized German city, except for one child who was recruited from a database of parents who had agreed to their participation in studies and tested in the Child Lab. No information was collected concerning the socioeconomic status of the individual participants’ families. The children at all day-care centers and in the database were predominantly White and middle-class. Parental consent was obtained in all cases.

Materials and design. We used the same eight unmodified items and novel adjectives as in Experiments 1 and 2. The toys were again always presented in the same order, with order of condition and use of adjective across condition being fully counterbalanced.

Procedure. We played the same requesting game as in Experiments 1 and 2 but with a few crucial differences. First, we used one plain item at a time in both the control and the accident condition. The only difference in the accident condition was that right after using the novel adjective and before the noun, E1 performed an additional gesture to indicate that he had misspoken. He covered his mouth with his hand and looked at the child while shaking his head. This additional gesture resulted in an average pause of 1.3 s between the adjective and the noun. In order to ensure that the conditions were maximally comparable, we added a brief pause in the control condition. The duration of the pause was measured in all cases and is considered in our analysis of the data. Each child went through eight trials, with alternating conditions. E1 and E2 provided help to the children in the same way they did in Experiments 1 and 2.

The warm-up was similar to that used for Experiments 1 and 2, with a few changes and additions. The slip-of-the-tongue gesture was briefly introduced to the children. The picture book now contained three additional items, and E1 made use of the gesture produced the correct label. During the four warm-up trials of the children identified the objects using the same labels, three of the children identified the shovel as a Schippe rather than a Schaufel, and as in Experiments 1 and 2, E1 then adopted this term.

Coding. Applying the same criteria as in Experiments 1 and 2, there was a total of four missing data points out of 128 trials. Coding of imitation was the same as in Experiments 1 and 2. The children’s productions were again counted as replication if they produced the novel adjective or a form phonologically similar to it. No attempts to replicate the gesture or pause were observed, and this was not coded. Data for a randomly chosen 25% of trials was further coded by a research assistant who had only the audio tracks of the recordings and was thus blind to condition. We found high agreement between coders (87.5%, κ = 0.773). In order to check for any effects of timing, we measured the duration, in milliseconds, of E1’s requests, as well as the length of the pause between adjective and object name. This was performed using the free software Audacity. A research assistant blind to the experimental question and conditions measured duration and pause in the same way for a randomly chosen 25% of trials. Reliability was assessed by computing the correlation between the two coders. Pearson’s r was greater than 0.99 for both pause and total duration, indicating high reliability.

Analysis. We analyzed our data using the same main procedures as were used in Experiments 1 and 2. To facilitate interpretation of the model parameters, we coded the accidental condition as 0 and the intentional (unmarked) condition as 1. Consideration of the possible effect of the addition of the pause to E1’s productions required some additional techniques. While we added a pause to E1’s utterances in the control condition in order to match the accidental condition as closely as possible, there remained a mean difference between conditions of 558 ms, t(128) = 16.38, p < .0001, d = 2.896. As the pause could potentially cause a difference in the time taken to produce the surrounding words, we also measured the full time taken to produce the utterance and found a mean difference of 554 ms, t(128) = 12.85, p < .0001, d = 2.272. A crucial question then is whether timing could explain the difference between conditions.

As the duration of the pause and the duration of the whole utterance are different measures, we wanted to consider their combined effect, but since they are highly correlated, we could not safely put them into the same models. We therefore performed a principal components analysis to reduce them to a single “duration” variable that accounted for 94.5% of their variance. We then examined the effect of this variable via model comparison. Since the fitting of our multinomial mixed models used penalized quasilikelihood (as is standard), we could not compare model likelihoods for the main reported models directly. We thus performed model comparison using the deviance information criterion (DIC; Spiegelhalter, Best, Carlin, & van der Linde, 2002) statistic, which we calculated using the MCMCglmm package (Hadfield, 2010). In order to additionally enable a traditional comparison, we collapsed replication and the use of other linguistic material before the noun into a single outcome category and fitted multilevel binary logistic models using Laplace approximation.

Results

The children’s responses are summarized in Figure 3. This stacked area chart shows the proportion of children who produced a given response for each of the four trials conducted in each condition (as in Experiments 1 and 2 the conditions were alternated, with the condition that came first being counterbalanced across children). As can be seen, children replicated the novel adjectives more in the control condition than in the accidental condition. The rate of replication can be seen to increase over the trials in both conditions. However, the children show a consis-
tently high rate of replication even in the different-categories condition (participant $M = 0.458$, 95% CI [0.260, 0.672]).

The fixed effects from our multinomial model are summarized in Table 3. The model shows that the participants were significantly more likely to prefer replication when the adjective was not marked as accidental than when it was, a difference that represents a sizable effect (an odds ratio of 4.12). As in the previous experiments, participants were also significantly more likely to produce a replication of E1’s production in later than in earlier trials, a pattern that has a similar effect size to that found in Experiments 1 and 2 (an odds ratio of 1.29). Participants were significantly more likely to produce the “other material” response in the accidental than in the control condition, an effect of a greater magnitude than in Experiments 1 or 2 (an odds ratio of 15.38, as opposed to 11.72 and 4.01 for Experiments 1 and 2, respectively). As in Experiments 1 and 2, trial number seemed to have no effect on the production of other linguistic material. The estimated log odds ratio for the replication response intercept is not significantly different from 0 (the ratio of the probability of this response and the bare noun response was not different from 1), meaning that the children showed no significant preference for dropping the novel adjective over producing it in the accidental condition. This again confirms that a high rate of replication was seen for even the condition that had (out of the two conditions) the lower proportion of replication. The HPD ranges observed for each of the parameters confirm the robustness of our reported effects.

As both condition and trial number were again found to affect the probability of children’s replicating E1’s novel adjective, we again looked at whether there was an interaction between these predictors for this response. We found that adding an interaction between condition and trial number did not improve the fit of the model, $\chi^2(1) = 1.57$, $p = .211$. The variance attributed to differences between participants (rather than to any aspect of the procedure; this is equivalent to the between-subjects variance component in a repeated measures analysis of variance) was again significantly greater than 0 for replication, $\chi^2(15) = 65.94$, $p < .001$, $\varphi = 0.51$, but not for the use of other linguistic material, $\chi^2(15) = 20.26$, $p = .162$, $\varphi = 0.28$.

One additional issue that we needed to address for this experiment is that the length of the pause between the adjective and the noun differed between conditions. A multinomial model containing duration, trial number, and condition was found to give a better fit (as indicated by a substantially lower DIC value) than did one containing just duration and trial number, meaning that condition explained variance above and beyond that accounted for by duration. Furthermore, a model containing just trial number and condition was found to have a better fit than did one containing just duration and trial number, indicating condition in isolation to be a more valuable predictor than was duration. As explained above, we additionally performed a binary logistic analysis over a collapsed data set. A model containing just trial number and condition provided a significantly better fit than did one containing just trial number and duration (as indicated by a lower Akaike’s information criterion value). A model with trial number, condition, and duration as predictors was found to be a significant improvement over a model containing just trial number and duration, $\chi^2(1) = 4.47$, $p = .035$, log-likelihood ratio index = 0.035, but a slightly

Table 3

| Summary of Fixed Effects for Multilevel Multinomial Regression Analysis for Experiment 3 |
|---------------------------------------------|---------------------------------------------|---------------------------------------------|---------------------------------------------|---------------------------------------------|---------------------------------------------|---------------------------------------------|
| HPD intervals                              | HPD intervals                              | HPD intervals                              | HPD intervals                              | HPD intervals                              | HPD intervals                              | HPD intervals                              |
| Estimate                                    | Lower                                      | Upper                                      | $SE$                                       | $T$ ratio                                   | $df$                                       | $p$                                        |
| Replication                                 | -0.442                                     | -2.456                                     | 1.155                                      | 0.651                                      | 15                                         | 0.507                                      |
| Condition                                   | 1.417                                      | 0.502                                      | 3.191                                      | 0.538                                      | 15                                         | 0.010                                      |
| Trial number                                | 0.251                                      | 0.049                                      | 0.624                                      | 0.118                                      | 15                                         | 0.035                                      |
| Other linguistic material                   | -4.043                                     | -9.848                                     | -2.526                                     | 1.201                                      | 15                                         | 0.005                                      |
| Condition                                   | 2.733                                      | 0.847                                      | 6.894                                      | 1.181                                      | 15                                         | 0.022                                      |
| Trial number                                | -0.275                                     | -0.940                                     | 0.159                                      | 0.228                                      | 15                                         | 0.232                                      |

Note. The accidental condition is coded as 0; the unmarked condition is coded as 1. HPD = 95% higher posterior density.
worse fit than a model containing just trial number and condition. This indicates that condition had a significant effect over and above any effect of duration.

Discussion of Experiment 3

In Experiment 3 we found that children were less likely to imitate a novel adjective when it was marked by the speaker as accidental. This suggests that the children were aware of the communicative intention of the experimenter and of the relationship between this intention and the form chosen, even in the absence of an awareness of the details of this relationship.

As in Experiments 1 and 2, we saw a small number of trials in which children used a familiar word in place of the novel adjective modeled. In this study it seems to be even clearer that the use of a familiar word is a response to the modeling by the experimenter. In each of the first two experiments, one of the conditions demanded the use of an adjective. However, in this experiment the adjective was redundant in all cases. Any tendency to use the adjective cannot be attributed to anything other than the adult’s use of the form. It is interesting, then, that the children were 8% more likely to use a familiar modifier in the control than in the accident condition. It appears that they were assuming that a modifier was required, based on the adult’s intentional use of one but replacing the unknown word with a familiar one.

As in Experiments 1 and 2, we here found a tendency for replication to increase as a function of trial number that did not seem to vary across conditions. It seems likely that the source of this trial effect is the same as that for the main effect—the children’s awareness of an act as intentional or unintentional. In our discussion of Experiments 1 and 2, we suggested that by repeating the redundant use of an adjective the speaker would reinforce that it was not an oversight but an intentional act. This seems likely to be driving the effect here too. The control condition was of course identical to the single-object condition from Experiment 1. In the accident condition, the children would not expect an adult to make a slip-of-the-tongue many times in quick succession. Thus, they might be expected, after some repetitions, to stop interpreting the experimenter’s gestures as indicating that a mistake was made. The picture is somewhat more striking in this experiment, where the main manipulation reduces rather than increases replication and where one might therefore have predicted an effect in the opposite direction—that as children become more competent they would produce the adjective less in the accident condition and hence we would see a decrease over trials. That they didn’t do so further emphasizes the role of a perceived connection between the means and the ends of the speaker and thus supports the claim that what is seen here is at least partially imitation and not mimicry. Nonetheless, it must be noted that even in the first trial in the accidental condition, the percentage of children who imitated the novel adjective was 20%, suggesting that, as previous work has shown (e.g., Snow, 1981), children sometimes mimic linguistic material without concern for the speaker’s goals.

It seems to be the case, then, that children sometimes avoid imitating material when they can infer that its use was accidental. When the material was not marked as accidental, however, the rate of imitation was, based purely on proportions over all trials, as high as 70% even though it was redundant in context. This is higher than in the identical condition in Experiment 1 and is in fact slightly higher even than the rate of imitation in the choice condition in Experiment 1. This difference between experiments could be attributed to the pause that was added in both conditions, which might have made the adjective easier to copy. Another possibility is that the inclusion of the accident condition in Experiment 3 highlighted for the children that the adjective in the control (single, unmodified object) condition was being used intentionally (as the experimenter did not mark it otherwise) and thus increased replication.

Conclusion

There are three main overall findings from the combined experiments reported above. First, we found that 3-year-olds engage in a high rate of replication (greater than 50%) of a novel adjective even when there is no communicative motivation for the inclusion of the word. Second, we found that the rate of replication increases by as much as 20% when the adjective has a descriptive or a contrastive function. Third, 3-year-olds were found to replicate the adjective less when it was marked as accidental. These findings suggest that imitation (rather than simply mimicry) plays a role in children’s language use. In our introduction we made a distinction between insightful imitation (the copying of an actor’s goal and means motivated by insight into why those particular means were chosen) and blind imitation (the copying of an actor’s goal and means without an awareness of why those particular means were chosen). Our findings suggest that both kinds of imitation play a role in children’s selection of linguistic forms.

So what does it mean that children are insightful in their imitation? First, it might be considered remarkable that they filter out the adjectives at all. That children should remove the redundant or misplaced linguistic material is consistent with theories of linguistic pragmatics such as that proposed by Grice (1975). In the single-object condition in Experiment 1 and the identical control condition in Experiment 3, there was a single plain object, meaning that the adjective was obscure (contravening Grice’s maxim of manner), irrelevant (contravening Grice’s maxim of relation), and potentially misleading or untrue (contravening Grice’s maxim of quality). In the different-categories condition in Experiment 2, the adjective had some relation to the object due to the modifications but was not necessary for disambiguation and was thus redundant (contravening Grice’s maxim of quantity). Furthermore, economic theory predicts that rational agents will seek to minimize costs (von Neumann & Morgenstern, 1944) and thus will avoid redundancy. However, much work has suggested that such optimal behavior is not straightforward for children who are still learning to refer.

Whitehurst (1976) found that children as old as 6 tended to produce underinformative utterances (providing insufficient information) in a referential communication task. When provided with an adult model producing contrastive referring terms, 6-year-olds were not underinformative but instead became redundant in their productions. Many other similar findings have been published. Whitehurst, Sonnenschein, and Ianfolla (1981) found that 5-year-olds seemed to confuse utterance length with information given, explaining the tendency to be overinformative. In a study that is more encouraging about young children’s abilities, Matthews, Lieven, and Tomasello (2007) found that children as young as 2 could be trained to produce informative linguistic expressions.
However, it was not clear whether children at any of the ages tested would be able to avoid redundancy. Our results suggest that 3-year-olds are able to do precisely this. There is a crucial difference between our study and these previous works, however. While they all used familiar words, we were looking at how children would behave with completely novel words. We attribute our findings to this difference. Whitehurst (1976, p. 82) wrote that “unless there are specific reasons to behave differently, children seem to operate on the principle that words are cheap.” We propose that novel words, which require additional effort to learn and produce for the first time, are more expensive, and thus the children in our study were more likely to pay attention to context in deciding whether to expend this additional effort.

What does this say about imitation? Determining the appropriate amount of information to give in a particular context seems to be tough for young children. And yet assuming that children are unable to determine what parts of utterances are necessary would severely limit the explanatory value of any kind of imitation in language learning. Children cannot acquire language by replication alone—they need to learn how to combine words in novel ways. The potential value of imitation in explaining language learning is thus hugely boosted by any evidence that children can engage in this kind of insightful imitation, as it provides a means by which children could learn by taking linguistic forms (even multiform linguistic forms) from adult speakers, while at the same time learning about the combinatorial principles that motivate their use.

The discovery of blind imitation (goal-focused imitation even in the absence of a clear communicative function) also has important implications for the passage of language development. It is consistent with an account of language learning in which children begin to produce linguistic forms before they have acquired a full understanding of why these forms are composed the way they are. The idea that early in development children produce sequences of words as unanalyzed wholes—what Clark (1974) referred to as “performing without competence” (p. 1)—has a long history (e.g., Peters, 1983; see Bannard & Matthews, 2008, for recent experimental evidence). Tomasello (2003) proposed that children acquire syntax by first acquiring unanalyzed sequences of words and then developing increasingly abstract constructions by breaking the sequences down into reusable units and noticing structural commonalities. Such an account requires children to imitate prior to fully determining function, and we have here reported evidence for this.

The blind imitation found in our studies is analogous to the often reported tendency for children to “overimitate” nonlinguistic actions (Horner & Whiten, 2005; Kenward, Karlsson, & Persson, 2011; Lyons, Young, & Keil, 2007; McGuigan, Makinson, & Whiten, 2011; McGuigan, Whiten, Flynn, & Horner, 2007; Nagell, Olguin, & Tomasello, 1993; Nielsen, 2006; Nielsen, Simcock, & Jenkins, 2008), and thus the debates in the larger literature about what cognitive mechanisms underlie overimitation are relevant here. There is some evidence that children tend to replicate the exact form of others’ actions more when they are socially engaged with the model (e.g., Nielsen, 2006; Nielsen et al., 2008), which suggests that the tendency toward overimitation serves a social function. Meanwhile, others have provided evidence that overimitation arises from children’s tendency to overattribute causal significance to the components of an adult’s complex actions (e.g., Lyons et al., 2007). Evidence that is inconsistent with this account was recently provided by Kenward et al. (2011), who suggested a third explanation for overimitation—that children copy because they have inferred a prescriptive norm and wish to comply with it. Clearly all three of these functions would be relevant in a language-learning context. Children must discover what purpose the words and grammatical properties of the language serve but will also seek to promote and sustain social interaction. At the same time, natural languages contain a great many seemingly arbitrary norms, and children, who are learning to do as adults do, will be motivated to be conventional. The extent to which linguistic imitation is determined by these different considerations is a fascinating question for future research.

A final interesting detail in this context is the relative maturity of the children in our experiments. It seems that children’s willingness to imitate forms that they have not fully analyzed might continue to play a role in a difficult task like adjective acquisition until a relatively late stage of development. The tendency to overimitate in other domains has been found to be greater in 5-year-olds (McGuigan et al., 2007) than in 3-year-olds and to be even greater again in adults (McGuigan et al., 2011). Nielsen (2006), following Uzgiris (1981), proposed that older children are more likely to imitate for social than for instrumental reasons. In a domain (like language) that involves the learning of arbitrary conventions, one might also expect to see an increase in strategically motivated imitation. Children might determine that since the speaker produced the adjective it is safest to expend the limited energy to follow suit despite the absence of any clear function—thus showing a willingness to trust the judgment of the adult model over their own estimation of what is contextually appropriate. Older children are able to use their insights in order to justify the choice of form, but that might be treated as merely another piece of evidence to justify the replication of the form, which is always the safest strategy. Further work is required to see whether children would employ such a strategy—continuing to imitate even when their insights offer them other ways in which to communicate.

References


(Appendix follows)
Appendix

Objects and Adjectives Used in the Experiments

Objects (and Modifications) Used in Experiments 1 and 2

**Warm-up.** toy airplane, key, die, balls (1 big, 1 small), ropes (1 short, 1 long), blocks (1 red, 1 blue), toy apes (1 dark, 1 light), flute (silver foil added), horse (blue card pieces added).

**Test.** flower (shining stickers added), duck (shining stickers added), shovel (pearls added), bottle (pearls added), glasses (cotton balls added), cup (cotton balls added), spoon (pipe cleaners added), bucket (pipe cleaners added), plate (Experiment 2 only), pencil (Experiment 2 only), book (Experiment 2 only), candle (Experiment 2 only).

Objects Used in Experiment 3

**Warm-up.** toy airplane, key, die, balls (1 big, 1 small), ropes (1 short, 1 long), blocks (1 red, 1 blue), toy apes (1 dark, 1 light).

**Test.** flower, duck, shovel, bottle, glasses, cup, spoon, bucket.

Novel Adjectives Used in Experiments

**Warm-up.** sabig, trossig.

**Test.** dilsig, impig, mesig, ducksig, lukig, fatzig, bernig, puckig.

Familiar Object Labels Used in Experiments (Alternative Labels in Parentheses)

**Warm-up.** Flugzeug, Schluessel, Wuerfel, Ball, Seil, Baustein, Affe, Floete (Experiments 1 and 2 only), Pferd (Experiments 1 and 2 only).

**Test.** Blume, Ente, Flasche, Schaufel (Schippe), Brille (Sonnenglas), Tasse, Loeffel, Eimer.

Received May 2, 2011
Revision received November 1, 2012
Accepted December 6, 2012