Signs are symbols: evidence from the Stroop task

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Abstract

Most languages use spoken arbitrary symbols to access the conceptual system. Moreover, the link from spoken words to meaning is demonstrably automatic. Sign languages, by contrast, employ manual gestures that are heavily iconic. Whether manual symbols can activate the conceptual system automatically is unclear. To address this question, here, we examine the propensity of arbitrary colour signs in American Sign Language to induce Stroop-interference. Three experiments elicited colour naming of coloured videos depicting colour ASL signs—either congruent or incongruent with the video colour—and an unrelated neutral condition. Results showed that colour identification is modulated by its congruency with the ASL sign, and this finding replicated irrespective of response mode—signing vs. button-press—and the presence of congruent trials. These findings indicate that arbitrary signs automatically activate their meanings. We conclude that the capacity to link arbitrary phonological forms and meanings is an amodal design feature of language.

Keywords: Stroop, automaticity, sign language, language universals, lexical access.

Spoken words typically consist of arbitrary pairings of phonological forms and meanings (Hockett, 1960). Moreover, an encounter with a word's phonological form activates its meaning automatically, even contrary to task demands (e.g., Bargh, 1992)--the numerous demonstrations of Stroop-like interference in spoken language amply attest to this fact (e.g., Stroop, 1935; MacLeod & MacDonald, 2000; for review see MacLeod, 1991). But whether the capacity to link arbitrary phonological forms and meanings is restricted to spoken language, or whether it is shared with sign languages remains an open question.

At stake is not whether visual symbols can access the lexicon—this fact is firmly established by the aforementioned Stroop literature with printed words. Printed words, however, are metalinguistic symbols for spoken language. In the case of manual signs, by contrast, it is the language system itself that relies on the manual/visual modality. Our question here is whether the language faculty acquires a similar design in systems that are divorced from the speech modality. That is, can arbitrary phonological forms automatically activate the conceptual system in languages embodied in manual gestures/visual signs?

The possibility that signed lexicons attain full automaticity is consistent with observations suggesting that signed and spoken languages share several aspects of their design and processing. Like spoken languages, sign languages exhibit duality of patterning—sentences are formed by combining meaningful units, which, in turn, are comprised of discrete, meaningless phonological elements (Hockett, 1960; Stokoe, 1960). Sign and spoken languages also have similar grammatical properties, including, *inter* *alia*, prosodic hierarchy (Brentari, 1998), sonority constraints (e.g., Stokoe, 1960; Perlmutter, 1992; Brentari, 1998), productive inflectional and derivational morphology (e.g., Arnoff, Meir, & Sandler, 2005) and arguably, basic word order (e.g., Sandler & Lillo-Martin, 2006). And when it comes to on-line processing, like speakers, signers exhibit phenomena such as "tip of the fingers" (Thompson, Emmorey, & Gollan, 2005), lexicality effects (Carreiras, Gutiérrez-Sigut, Baquero, & Corina, 2008) and semantic priming (Emmorey, 1991; Corina & Emmorey, 1993; Bosworth & Emmorey, 2010). These observations suggest that, like spoken language, the lexicon of signed language is organized in an associative manner, as related words tend to activate each other. Given these observations, one might conclude that arbitrary signs can access the conceptual system automatically (i.e., even contrary to task demands). Surprisingly, the evidence to support this claim is absent.

Stroop-like interference offers the gold standard for demonstrating automatic activation of meaning. But unlike the countless Stroop studies of spoken languages (MacLeod, 1991), only one Stroop[1] study examined a sign language (i.e., American Sign Language) and results were inconclusive. Marschark & Shroyer (1993) presented participants with still images of ASL colour signs, such that the signer's hands were painted in colours. Participants were asked to sign the colour of the hands while ignoring their linguistic content. The researchers reported that Deaf participants were sensitive to colour-sign congruency, but the results for the congruent and incongruent conditions were not provided (only difference scores between incongruent and baseline trials were). Moreover, given the use of static images, one further wonders whether such effects, if found, generalize to naturalistic dynamic signs.

In a more recent study, Thompson, Vinson, & Vigliocco (2010a)[2] compared the automatic activation of meaning from iconic and arbitrary sign forms. In their study, participants were asked to ignore the signs' meaning, and indicate only whether the fingers were bent. Results showed that iconic signs elicited slower responses than arbitrary ones. These findings suggest that participants cannot help but access the meaning of iconic forms and consequently, their meaning interfered with reporting the shape of the fingers. Crucially, the stronger effect of meaning interference for iconic signs leads one to wonder whether lexical access to arbitrary signs is likewise automatic. Thompson and colleagues concluded that iconic signs form a special class of signs whose meanings are accessed more readily than those of arbitrary signs. But whether arbitrary signs are accessed automatically is unclear from these findings--the study did not directly address this question.

Iconic and arbitrary signs, however, could conceivably rely on different routes to access the conceptual system. In the case of iconic signs, signers could access meaning directly from their (nonlinguistic) visual forms. For example, the iconic ASL sign for "cat" (depicting whiskers) could rely on the nonlinguistic visual depiction of whiskers to access the concept of [WHISKERS], which, in turn, could activate [CAT]. In contrast, for arbitrary signs, meanings can only be retrieved from their linguistic phonological forms. Crucially, if the proportion of iconic signs in a language is high (as is typical in sign languages, e.g., Taub, 2001), then the link from phonological forms to meaning may be less practiced, hence it might become a secondary, less automatic route of lexical access.

Additional evidence concerning the automaticity of lexical access to signs is presented by research employing the Picture-Sign Interference procedure (Baus, Gutiérrez-Sigut, Quer, & Carreiras, 2008; Corina & Hildebrandt, 2002; Corina & Knapp, 2006). In these studies, participants were asked to name a picture in the presence of a distractor--either one that is semantically related to the target, phonologically related or unrelated. Results showed that picture naming is subject to inference from semantically related distractor signs. Although this finding is consistent with the hypothesis of automatic lexical access, the conclusion is uncertain. All existing demonstrations of picture-sign interference come from studies featuring an undifferentiated mixture of iconic and arbitrary signs. Given Thompson et al. (2010a)'s findings above, it is unclear whether these conclusions might hold for arbitrary signs, specifically. In addition, since most distractors were related to the target (phonologically or semantically), target processing could have been promoted by strategic control, rather than by an automatic process (i.e., one that runs contrary to task demands).

In summary, while the many similarities between signed and spoken languages might lead one to expect that lexical access to signs is automatic, the evidence to support this claim is missing. And given the prevalence of iconicity in sign languages and its demonstrable role in on-line processing, there is some reason to question the automaticity of form-meaning pairings. Thus, whether the capacity to use arbitrary phonological forms to automatically access meanings is limited to spoken language, or whether it generalizes to all natural languages –spoken and signed—remains an open question.

To address this question, our following experiments examine the sensitivity of Deaf participants to Stroop interference in ASL colour signs. All colour signs employed by our experiments were expressed by arbitrary forms that exhibit no discernible iconic links to their meanings. Participants were presented with dynamic ASL signs—either the signs for colours (BLUE, GREEN, YELLOW) or a neutral novel control sign (i.e., the novel sign XX). For each video, the signer appeared in one colour (blue, green or yellow). Thus, in relation to video colour, signs either were congruent (e.g., the sign BLUE in the colour blue), incongruent (e.g., the sign BLUE in the colour green), or unrelated (i.e., the neutral novel sign XX in any colour). Participants were asked to identify and sign the colour of the video while ignoring the colour that the sign expressed. If signers automatically activate the meanings of arbitrary sign forms, then we should observe the Stroop interference. Specifically, signers should be slower to name the video colour in incongruent trials (e.g., the sign BLUE in the colour green) relative to neutral ones (e.g., the neutral novel sign XX in the colour green).

Participants in Experiment 1 were presented with all three congruency conditions. To discourage strategic processing of the signs, Experiment 2 replicated this design without the congruent condition. Finally, Experiment 3 controlled for the effect of response competition by eliciting button-press responses.

Experiment 1

Method

Participants

Participants were 10 culturally Deaf, fluent ASL signers. Most (9/10) participants acquired ASL between birth and age five; and four of those had Deaf parents. The remaining participant acquired written English as a first language and used homesigns until acquiring ASL at age 15. All participants were paid $20 for their participation.

Materials

The materials consisted of video recordings of three colour signs (BLUE, GREEN, and YELLOW) [3] and a neutral novel sign (XX). The neutral novel sign was created by replacing the handshape in the aforementioned colour signs with the ASL X handshape. This neutral item was chosen because it is phonotactically matched to the colour signs but does not carry semantic information. Note that all signs used were matched for location, palm-orientation, and movement – differing only in handshape (i.e., signs were *minimal pairs*, akin to English words such as *red* and *bed*; e.g. Brentari, 1998). All materials were produced by a fluent signer.

These videos were cropped such that the signer was visible from the waist up. Next, they were edited using Final Cut Pro software so that the signer‘s entire body appeared in a single colour (blue, green, or yellow) on a black background. Thus, the meaning of the depicted ASL sign and the colour of the signer’s body were either congruent (e.g., the sign BLUE in the colour blue), incongruent (e.g., the sign BLUE in the colour green) or neutral (i.e., the novel sign XX in any colour). Examples are provided in the Supplementary Materials.

The experiment included a total of 180 trials (60 congruent, 60 incongruent, and 60 neutral), generated by fully crossing the three congruency conditions (congruent, incongruent, neutral) with the three colours (blue, green, yellow). Each experimental session was preceded by 12 practice trials (3 congruent, 3 neutral, 6 incongruent) – such that each possible sign-colour combination was displayed once in the practice. Trial order was randomized.

Procedure

Each trial began with a fixation point (+), presented for 500ms, followed by a monochromatic ASL video. Participants were asked to sign the colour of the video as quickly and accurately as possible. A fluent ASL signer, blind to the experimental conditions, coded each response on-line, by pressing the appropriate key as soon as the participant began to articulate their response. The experimenter's coding response automatically triggered the next trial.

Results & Discussion

In Experiments 1-2, outliers were defined as responses falling 2.5 standard deviations above the mean, or faster than 200 ms (less than 3.5% of total correct responses).

Figure 1 plots response time and proportion errors as a function of colour-sign congruency. A one-way ANOVA examining the effect of congruency (congruent, incongruent, neutral) yielded a significant effect in response time, $F(2,18 =31.34$, $MSE=614$, $p<.001$, and a marginally significant effect in accuracy, $F(2,18)=3.46$, $MSE=.0004$, $p =.053$. Planned contrasts showed that incongruent signs produced slower $\Delta=42.45$ms, $t(18) =14.67$, $p<.002$ and less accurate responses, $\Delta=-0.02$, $t(18)=4.56$, $p<.05$, compared to the neutral condition, whereas congruent signs facilitated response time, $\Delta=45.3$ ms, $t(18)=16.71$, $p<.001$. These results show that Deaf signers are sensitive to the congruency between the meaning of ASL signs and their colour, a result that mirrors the findings from spoken language.

Experiment 2

Why are signers sensitive to the colour-sign congruency? One possibility is that this effect reflects the automatic activation of the signs' meanings. But on an alternative account, the effect may be due to a response strategy. In this view, participants deliberately access the sign's meaning to enhance task performance. And indeed, such strategy would benefit performance on congruent trials (Logan & Zbrodoff, 1979). To test this possibility, Experiment 2 repeats the same procedure while excluding the congruent trials. If the results of Experiment 1 are solely due to a deliberate response strategy, then this change should eliminate the incongruency effect. Conversely, if they reflect an automatic link between arbitrary phonological form and meaning, then the incongruency effect should persist.

Method

Participants

Participants were 10 culturally Deaf, fluent ASL signers. One participant's data were excluded from all analyses because he was reportedly colour-blind. Most (8/9) remaining participants acquired a sign language before the age of five. Of these, six acquired ASL as their first language and two first acquired Signed Exact English (SEE – a sign hybrid that uses ASL signs with English syntax). The remaining participant learned English as a first language and later acquired ASL at age 23. Participants in this experiment also took part in Experiment 3, in counterbalanced order. No participants from Experiment 1 took part in Experiments 2-3. All participants were compensated $20 for their participation.

Materials & Procedure

The materials and procedure were identical to Experiment 1, except only incongruent and neutral trials were included in this experiment (120 experimental trials, 9 practice trials).

Results & Discussion

Figure 2 plots response time and proportion errors as a function of congruency. A one-way ANOVA of the effect of incongruency (incongruent, neutral) yielded a significant effect in response time, $F(1,8)=8.184$, $MSE=694$, $p<.03$; for accuracy $F(1,8,)=1.7$, $MSE=.0002$, $p=.22$. Participants responded significantly slower to the incongruent condition compared to the neutral condition, Δ=35.53ms. These results demonstrate that the effect of incongruency is not contingent on the presence of congruent trials.

Experiment 3

The persistent effect of incongruency with ASL signs, irrespective of whether congruent trials are present (in Experiment 1) or absent (in Experiment 2) is consistent with the hypothesis that signers automatically link arbitrary phonological forms and meanings. But on an alternative account, these findings could result from response competition. In this view, signers tacitly articulate (i.e., gesture) the signs as they are viewing them. Such tacit gesturing would facilitate correct responses to congruent trials, but could interfere with neutral and incongruent trials. Since the neutral novel sign XX is unfamiliar, its simulation might be less likely, resulting in weaker interference in the neutral condition relative to the incongruent one. Thus, responses in Experiments 1-2 could reflect not automatic lexical access but response competition. To address similar concerns, past research with spoken language has resorted to button-press responses. These studies have reported a smaller, but consistent effect of incongruency (e.g. Redding & Gerjets, 1977; White 1969).

To examine the role of response competition, Experiment 3 replicates Experiment 1 using button-press responses. If the Stroop-like interference with signs is solely due to response competition, then this effect should be eliminated in the present experiment. Conversely, if it reflects semantic interference, and if access to meaning is automatic, then the findings should emerge irrespective of whether a linguistic (signed) or non-linguistic (button-press) response is required.

Method

Materials & Procedure

Materials and procedure were identical to Experiment 1, except that responses were given by a button-press rather than by signing.

Results & Discussion

Figure 3 plots response time and proportion errors as a function of congruency. A one-way ANOVA of the effect of congruency (congruent, incongruent, neutral) yielded a significant main effect in response time[4], $F(2,16)=4.18$, $MSE=662$, $p<.04$; in accuracy $F(2, 16)=1.5$, $MSE=.0001$, $p=.25$. Planned contrasts showed that incongruent signs produced slower responses compared to neutral ones, $\Delta=28.98$ms, $t(16)=5.71$, $p<.03$.

Congruent signs, however, no longer facilitated response time, Δ=2.58ms, $t(16)=0.045$, $p=.83$).

The absence of facilitation from congruent trials in the present experiment mirrors findings from button-press Stroop experiments in spoken language (e.g., Darymple-Alford, 1972). This null effect could suggest that the congruency facilitation largely occurs at the response stage. Alternatively, the congruency facilitation could have been eliminated due to the greater speed of the button-press response, M=744ms, as compared to the signed response, M=1189ms, $t(8)=9.56$, $p<.001$. The finding that button-press responses diminish the facilitation from congruent signs also sheds lights on the origins of this phenomenon in the spoken language literature. In the case of spoken language, it is often unclear whether the diminished congruency facilitation for manual responses is due to the change in response modality (from spoken naming to manual press) or the change in the linguistic status of the response (speech response is linguistic, manual response is not). Finding that the same phenomenon obtains with sign language (where language uses the manual modality) favours the linguistic explanation. Congruency facilitation effects may thus reflect facilitation between the articulatory linguistic responses that mediate responses—spoken or manual. Our key finding, however, concerns the effect of incongruency. Results make it clear that the use of button-press responses did not eliminate the colour-sign interference. These findings rule out the possibility that the Stroop interference solely results from response competition.

General Discussion

Most natural languages use spoken symbols to access the conceptual system. Moreover, most spoken words consist of arbitrary pairings of phonological forms and meanings. Sign languages, by contrast, rely on manual gestures, and in the manual modality, iconic forms reign supreme (e.g., Taub, 2001). Existing research further suggests that signers employ iconicity information in on-line language processing, as iconic signs appear to activate their meanings more readily than arbitrary phonological forms (Thompson et al., 2010a). Given these findings, one wonders whether arbitrary signs can automatically activate their meanings from their phonological forms. To address this question, the present study examined whether arbitrary ASL signs automatically activate their meanings using the Stroop paradigm.

The findings in Experiments 1-3 demonstrate that ASL signers are sensitive to colour-sign congruency. Experiment 1 showed that colour naming is impaired when the sign's meaning is incongruent with its colour. This interference is not due to the deliberate processing of the sign, as similar results are obtained even in the absence of congruent trials (in Experiment 2). The colour-sign interference is likewise not due to response competition, as the Stroop interference replicates even when participants deliver their responses by pressing a button (in Experiment 3). Together, these results suggest that fluent ASL signers automatically access the meanings of arbitrary colour signs from their phonological forms.

Our present results converge with the previous pioneering Stroop study by Marschark and Shroyer (1993) as well as findings from the Picture-Sign Interference paradigm (Baus et al., 2008; Corina & Hildebrandt, 2002; Corina & Knapp, 2006) and the Handshape judgment study (Thompson et al., 2010a). While these previous results all point out to the possibility that lexical access to arbitrary signs might be automatic, our experiments secure this conclusion by demonstrating for the first time that signers access the meaning of arbitrary signs even when the processing of signs is discouraged by task demands. These results suggest that an automatic link between arbitrary phonological form and meaning may be an amodal feature of the language system.

word count: 2997

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Figure Captions

Figure 1. The congruency effect in Experiment 1. Note: Error bars are confidence intervals, constructed for the difference between the means.

Figure 2. The incongruency effect in Experiment 2. Note: Error bars are confidence intervals, constructed for the difference between the means.

Figure 3. The congruency effect in Experiment 3 (using button-press responses). Note: Error bars are confidence intervals, constructed for the difference between the means.

Footnotes

[1] Vaid & Corina (1989) used a Stroop variant to demonstrate interference between still, iconic number signs and their incongruent physical size. But because participants were instructed to attend to the signs (rather than their physical size), the observed interference reflects the automatic encoding of physical size, rather than the automaticity of phonological form-meaning pairings.

[2] Thompson, Skinner, Vinson, Fox, & Vigliocco (2010b) attempted to address this question as well. In this study, however, signers were asked to state the directionality of the movement (up or down) and ignore the signs' meaning. Unlike the handshape judgment (in Thompson et al., 2010a), the movement judgment task elicited attention to a dimension that is potentially related to the meanings of many iconic signs. For example, the downward movement in the iconic sign CRY is related to the sign's meaning, as tears fall down. Accordingly, movement judgment does not present evaluation of the activation of meaning in contrary to task demands.

[3] We invariably used only the disyllabic reduplicated variants of these signs.

[4] Unlike the previous experiments, in Experiment 3, no responses were eliminated from the analysis of response time, as all responses were fast (< 2.5 seconds), and our cutoff criterion (2.5 SD above the mean) disproportionally penalizes incongruent trials (3.6% compared to 1.8% neutral trials).