Method Article

A method to measure Representatativity and Univocity of traffic signs and to test their effect on movement

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A B S T R A C T

Objective: The present protocol aims to understand how participants represent traffic signs (Psychology of Thinking) and how the attention of these signs—and the way of processing them—can influence on their path movement (Motor Processes). Knowing how humans process the meaning of signs (not just by learning but instinctively understood) will improve reaction times and decision making when driving.

Background: In laboratory tasks, a number of models have attempted to explain the general relationship between attention and movement. The cornerstone of the effects is found on the meaning of attentional cues.

Method: By using a tracking task, the influence of traffic signs on movement has been tested.

Results: Results point out that the signs least representative of their meaning produce a greater deviation from the center of the simulated road than the most representative signs.

Conclusions: The economic, social and psychological consequences of car accidents are well-established. Every single effort orientated to amend this social problem is welcome. Taking into account the results reported in this work, it is recommended that the traffic signs are designed as much representative of their meaning as possible.

Application: The methodology used in this study can be applied to testing the Cognitive Ergonomics of signposting on roads; analyzing, classifying, and discarding the traffic signs that produce counterproductive effects on movement from the current Manuals of Traffic Signposting all around countries.

- An original methodology has been generated for classifying traffic signs, which has not been never tested in the literature.
- The well-consolidated tracking task is used for evaluating their effect on movement.
- The main result is that traffic signs, that do not represent properly their meaning, provoke a significant and dangerous deviation from the drivers’ path.

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Method details

The present method is a protocol in which three experiments, first of all, classify traffic signs and, afterward, check the possible effect of representativity and univocity of signs on movement. However, k-means analysis and ANOVA are not new.

Experiment 1 (to classify traffic signs)

In this experiment, Reaction Times (RTs) are measured in response to the presentation of a serial of traffic signs. Participants have to decide if a previous definition of a sign corresponded to the sign presented at that moment.

The representativeness of signs is defined as the degree to which they reflect features of their parent population. On the other hand, univocity is defined as the absence of polysemy (more than one meaning).

Therefore, these two concepts are operationalized as (cf. [1–3]): (a) if the sign really represents its meaning (representative sign), before the right matched definition-sign, RTs will be shorter than when the sign does not represent that meaning; (b) if the sign is not ambiguous (univocal sign), before the wrong matched definition-sign, RTs will be shorter than when the sign is ambiguous.

Stimuli

From the population of traffic sign icons specified in any “Manual of Traffic Signposting” of any National Road Safety Commission, informative, warning or regulatory signs can be selected for the study (e.g., Fig. 1). It can be used a selection criterion based on whether the element—that the sign tries to represent—is inserted either on the road or nearby. Distant elements from the road could be discarded. The reason for this decision is that mental models of the elements (e.g., [4]) closer to the route are more likely to cause an interference on movement [5]. Within this criteria, the secondary criterion can be: Same signs with different colors are randomly selected (since the color has not significant effect on the representativity or the univocity of traffic signs; [1–3]). The meaning of the sign is independent of the color they have (see Fig. 2). For example, white, green and blue colors just indicate the type of the road (regional road, freeway, or highway respectively) where the drivers are
traveling on. On the other hand, the definition of signs can be extracted from their legal frame. Table 1 presents the translation of examples of definitions regarding informative signs.

**Materials and task**

A plain computer can be used to present stimuli and record participants’ responses, by means of OpenSesame™ program [7].

In a computer screen, definitions of signs are presented after a fixation cross (see Fig. 3), this presentation lasted as long as the participant does not push the spacebar key. These definitions could match or not with the actual sign presented afterward. The definitions, that mismatch their signs, are presented randomly. Participants have to decide if the definition corresponded or not to the sign, by pressing “s” (congruence trials) or “k” keys (incongruence trials) respectively, as an example.

**Procedure**

Once participants are seated comfortably (and after having fulfilled the informed consent form), they are given the instructions of the task. The instructions specify that, on a single trial, any given definition of a traffic sign will be presented and, after the sign disappearance, they have to decide if that sign really represented the meaning of the definition previously shown.
The signs are presented with their match definition or with any other mismatch definition (randomly extracted from a population of definitions). Therefore, for each sign, there are two kinds of trial (congruent/incongruent). A complete block is constituted by the match and the mismatch trials. The total number of blocks can be decided depending on the total number of traffic signs selected.

Data analysis

All RTs are submitted to a k-means analysis to cluster signs with equivalent responses. K-means is a vector quantization in which every observation belongs to the cluster with the nearest centroid [6]. This centroid is calculated based on the distribution of data, not the mere mean. This analysis make it possible to cluster not only signs (observations) that have similar means but signs that have similar pattern of response; similar distribution of TRs. In this sense, two kinds of RTs, regarding the concepts of representativity and univocity, are analyzed. On the one hand, TRs for the matched definition-sign are clustered on Representative signs and Non-representative signs. On the other hand, for the mismatched definition-sign, RTs are clustered on Univocal signs and Ambiguous sign. One-way ANOVA test is carried out to compare the differences between both created groups of signs in their RT means between the both groups within the both concepts (representativity and univocity).

In order to check the significant relationship between representative/non-representative signs and the number of errors committed in the decision task for each group, the contingent table for these matches is submitted to $\chi^2$ test; $\phi$ coefficient is used to measure the magnitude of that correlation.

Experiment 2 & 3

Overview

Taking into account the different cluster groups created in Experiment 1, the most “representative” signs of each group (the ones closest to the center of both cluster within the both constructs of representativity and univocity; see Tables 2 and 3 and Fig. 4 as an example) are separately introduced.
Table 1
Translation of the sign definitions used in the experiment 1.

| Codification | Definition |
|--------------|------------|
| I1           | Route to follow in an intersection |
| I2           | Coming emergency track |
| I3           | Perpendicular route exclusive for public transport |
| I4           | Direction to abandon the road |
| I5           | Distance to the next way out |
| I6           | Confirmation to the coming destinations and their distances |
| I7           | Pan-American highway |
| I8           | Number of the highway you are driving in |
| I9           | Name of the street and point on the road |
| I10          | Interest point announcement |
| I11          | Restaurant |
| I12          | Accommodation |
| I13          | Cash machine |
| I14          | Service station |
| I15          | Restroom |
| I16          | Public phone |
| I17          | Freeway beginning |
| I18          | Freeway ending |
| I19          | Side way out |
| I20          | Last way out before freeway |
| I21          | U-turn |
| I22          | Place to park |
| I23          | Emergency phone |
| I24          | Freeway with "telepayment"* |
| I25          | Tollbooth |
| I26          | Weigh station |
| I27          | Bus stop |
| I28          | Radar control |

Note.
* System to automatically pay the turnpike.

Table 2
K-means clustering based on the RTs to respond to each sign.

| Representative signs | Distance to cluster center | Sign | Non-representative signs | Distance to cluster center | Sign |
|----------------------|----------------------------|------|--------------------------|----------------------------|------|
| 357.38               | I28*                       | 632.44 | I7*                      |
| 404.60               | I21*                       | 715.56 | I18*                     |
| 407.32               | I14*                       | 730.59 | I124*                    |
| 462.97               | I12*                       | 835.46 | I17*                     |
| 476.82               | I15*                       | 884.72 | I13*                     |
| 495.03               | I23*                       | 912.46 | I15*                     |
| 501.75               | I6*                        | 966.64 | I125*                    |
| 523.70               | I11*                       | 1007.44 | I122*               |
| 571.25               | I13                        | 1025.04 | I1              |
| 619.94               | I16                        | 1040.55 | I14             |
| 673.84               | I18                        | 1087.58 | I2             |
| 675.63               | I27                        | 1141.75 | I126            |
| 702.94               | I19                        | 1548.92 | I120            |
| 750.62               | I9                         |       |                       |
| 895.99               | I10                        |       |                       |

Note.
* Signs selected in each group (Representative signs and Non-representative signs) for experiment 2.
into a tracking task [8]. Since, when individuals do not understand any piece of information, they move closer to the source of that information (e.g., [5]), the first hypothesis is that the non-representative signs produce a differential influence on movement, as shown in previous literature ([1–3]). This effect will take the form of a significant greater deviation (from the center of the road) for non-representative signs than for representative signs. The second hypothesis is that, since univocal and ambiguous signs have, at least, one meaning, these signs would not deviate significantly the movement to them. In Experiment 2 and 3, the paradigm of Vilchez [5] to measure the influence of the attention-to-stimuli on movement is used.

**Stimuli**

A 60-pixels-wide, gray road is presented on 800-pixels-wide, green backgrounds in a computer screen. The simulated road is limited by two continuous, white lines and divided in two by a 3-pixels-wide, discontinuous, white line (see Fig. 5). Two kinds of background were presented: non-experimental and experimental backgrounds. Non-experimental backgrounds are created with several routes where the road turned right and left (see [5], for a detailed description of the methodology).

The participants controlled a green circle of 22-pixels-wide in diameter, with a black circumference and a central dot (see Fig. 6). Traffic signs (see Fig. 4) were superimposed on both sides of the road before a Y-junction in experimental backgrounds (see Fig. 7 as an example).

**Materials and tracking task**

A plain computer can be used to present stimuli and recorded participants’ trajectory movement. Participants drive the green circle stimulus with a steering wheel. The steering wheel movements modified the position of the center of the green circle on the x-axis. Its position on the y-axis is fixed at a specific location (see [5], as a reference). Backgrounds ran across the screen, giving the feeling of movement.

The aim of the task is to track the center of the simulated road with the green circle during proximately 20 min. The road is designed by using a randomized sequence of backgrounds. However,
Fig. 4. Selected signs in representativity (representative signs and non-representative signs) and univocity (univocal signs and ambiguous signs).
In every trial, only one sign is presented at the same time, in any side of the road, and only in experimental backgrounds. The sign appears approximately 123 pixels before the Y-junction, 70 pixels from the center of the road, and during 6 registered frames (each frame with an average duration of 60 ms).
Procedure

Once participants are seated comfortably, and after having fulfilled the informed consent form, they are given the instructions of the task. The instructions specify the possible appearance of a distractor (the traffic signs) during the performance of the task and the free-option to take the route that participants wanted to in the Y-junction; in experimental backgrounds (see Fig. 5 as a reference).

Data analysis

The total number of data rows (or registered frames) is exactly 17,601 per participant. Data was filtrated by experimental conditions and different measure stages (previous or subsequent to the signs presentation). In the first measurement stage, the space right before the picture presentation (pre-cue stage or A frames) is codified as General-movement control condition. During the second measurement stage—the space where the sign is being presented (cue-appearance stage or B frames)—, the codification depends on the experimental conditions of that particular trial. In the third measurement stage—the space where the sign disappears (post-cue stage or C frames)—, the codification depends on the experimental condition of the previous second stage.

The error is calculated by subtracting, frame by frame, the position of the center of the road from the x-position of the green circle. Repeated measures ANOVA $2 \times 2$ (Position x Representativity) is conducted on every experimental frame belonging to cue-appearance (B frames) and post-cue (C frames) stages. Pre-cue General-movement control stage (A frames) is not included in the analysis because, in this stage, the different experimental conditions are not presented.

On the other hand, the two possible routes to take in the Y-junction in experimental backgrounds are also analyzed. To this end, the count of times every participant choses a specific option is weighted to the total number of possible choices. Data is subjected to a Kendall’s W coefficient of concordance test, focusing only on one option (right route) because the branch options are symmetrical, that is to say, taking the right route is equivalent to non-taking the left route within a specific trial.

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