Quantifying the Consistency of Gesture Articulation for Users with Low Vision with the Dissimilarity-Consensus Method

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ABSTRACT

We apply the dissimilarity-consensus method to quantify and report the articulation consistency of gestures produced on touchscreens by users with low vision, which we compare to the consistency of people without visual impairments. We report results in terms of dissimilarity-consensus growth curves and logistic models on a public dataset of 6,562 stroke-gestures collected from 54 participants, of which 27 with low vision. Our empirical results show that participants with low vision were 28% less consistent in their gesture articulations compared to the participants without visual impairments. We also demonstrate the suitability of the method, applied so far for whole-body gestures only, for the analysis of touchscreen stroke-gestures.

CCS CONCEPTS

• **Human-centered computing** → **Gestural input**; **Empirical studies in accessibility**.

KEYWORDS

low vision; stroke gestures; gesture analysis; dissimilarity; consensus

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1 INTRODUCTION

Touch and stroke-gesture input, in the form of taps, swipes, flicks, and symbolic shapes, are predominant for interacting with mobile and wearable devices with touchscreens. While taps implement a visual process requiring users to focus their visual attention to the intended target, stroke-gesture input can be performed in eyes-free contexts of use and, thus, is better suited for users with visual impairments to interact with touchscreen devices [4,6,7,10]. To this end, design knowledge regarding how users with visual impairments articulate stroke-gestures on touchscreens and the gestures they prefer to use [12] is needed to inform effective gesture sets and recognizers [4,7].

Gesture articulation encompasses many aspects, from the geometry of gesture paths to production speed and to the order in which the individual strokes that form a multi-stroke gesture are entered; see Figure 1 for a few examples of stroke-gestures used in this work. Gestures that are consistently articulated by users reduce the complexity demands of recognition algorithms [14] and facilitate formation of high-consensus gesture sets for intuitive gesture-based user interfaces [13]. The articulation consistency of stroke-gestures has been evaluated using agreement rate measures [1,10]. Recently, a new method based on dissimilarity-consensus curves and logistic models [8] was introduced as an alternative technique, but demonstrated for whole-body input only.

The contributions of this work are as follows: (1) we present the first application of the dissimilarity-consensus method [8] to stroke-gestures produced on touchscreens to confirm the method suitability for other gesture types than whole-body input; (2) we report empirical results for stroke-gestures articulated by users with low vision and compare their articulation consistency with that of users without visual impairments. Our results on a public dataset [10] of 6,562 samples collected from 54 participants reveal 28% less consistency for users with low vision.

2 THE DISSIMILARITY-CONSENSUS METHOD

The dissimilarity-consensus method (τ-C) was introduced by Vatavu [8] to reduce the effort of manually analyzing and clustering gesture datasets in end-user gesture elicitation studies [13]. The method consists of using a gesture dissimilarity function δ, such as Dynamic Time Warping (DTW) [5,7,14], $1 [14], or $P/$P+ [7,9], together with a threshold τ. Two gestures are considered similar enough to be clustered into the same class if the dissimilarity between them is less than τ. The τ threshold is varied from 0 (when all the gestures are considered different) to ∞ (all the gestures are similar), and consensus (consistency in this paper) among gestures is computed as follows:

$$C(\tau) = \frac{\sum_{i=1}^{N}\sum_{j=i+1}^{N}\left[\xi\left(\delta(g_{i,t}, g_{j,u})\,\forall t,u\right) \leq \tau\right]}{0.5N(N-1)} \quad (1)$$

where N is the number of users that were elicited for gestures, $g_{i,t}$ and $g_{j,u}$ are two gesture samples from users i and j, δ is the dissimilarity, and ξ an aggregator function that produces one single value for comparisons involving multiple gestures when the same gesture was repeatedly collected from the same user; see [8, pp.

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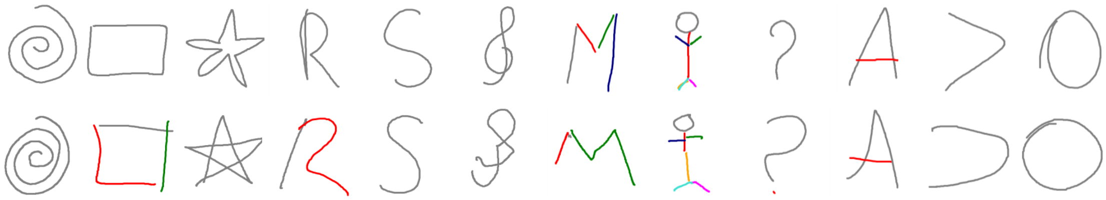

Figure 1: Examples of stroke-gestures produced by people without visual impairments (top row) and with low vision (bottom row) from the public gesture dataset of Vatavu *et al.* [10]. *Note:* Following Anthony *et al.* [1], colors show stroke orderings.

4-5]. The τ-C curve is the functional relationship from Eq. 1 that describes how consistency $C(\tau)$ varies with τ. This relationship is modeled with a logistic function:

$$C(\tau) = \frac{C_\infty \cdot C_0}{C_0 + (C_\infty - C_0) \cdot exp(-r \cdot \tau)} \tag{2}$$

where the growth rate r is an indicator of consistency, i.e., the faster the τ-C curve grows, the more consistency there is in the gestures from which the curve was computed; see Figure 2 for examples. The values of the C_0/C_∞ parameters are estimated so that the logistic model best fits the observed dissimilarity-consensus data.

3 EXPERIMENT

We applied the dissimilarity-consensus method [8] to stroke-gestures produced on touchscreens by people with low vision and without visual impairments.

3.1 Dataset

We employed the public stroke-gesture dataset of Vatavu *et al.* [10] consisting in 6,562 samples of 12 distinct stroke-gesture types collected using a tablet from 54 participants, of which 27 with low vision; see Figure 1 for a visual illustration of several gestures from this dataset. The dataset is freely available to download from the web page http://www.eed.usv.ro/~vatavu/projects/LowVisionGestureDataset.

3.2 Method

We measured the consistency in gesture articulation as the growth rate r of the logistic functions (Eq. 2) used to model the dissimilarity-consensus curves (Eq. 1) computed for each gesture type and each user group (users with low vision and without visual impairments, respectively). We used the DTW function [5,7] to compute the dissimilarity between gestures, and we normalized DTW values by dividing them to the number of point alignments [8].

4 RESULTS

Figure 2 illustrates the τ-C growth curves for each gesture type and user group and Table 1 shows the average values of the parameters of the logistic model from Eq. 2. Figure 2 reveals a visual good fit between the logistic models (shown in black color) and the dissimilarity-consensus curves (green and orange, respectively) for all the gesture types and user groups. Table 1 confirms this observation: the values of the C_0 parameter are close to zero (M=0.91, SD=0.51 for users with low vision and M=1.50, SD=1.72 for users without visual impairments), and the values of C_∞ are close to 100 (M=96.51, SD=3.89 and M=97.64, SD=2.95, respectively). All the

Table 1: Average values for the parameters of the logistic functions (Eq. 2) used to model the dissimilarity-consensus growth curves shown in Figure 2.

Measure	Low vision	No visual impairments
r	6.53	8.38
SE	0.36	0.29
p	<.001	<.001
C_0	0.91	1.50
SD	0.51	1.72
C_∞	96.51	97.64
SD	3.89	2.95

growth rates shown in Figure 2 were found significant at p<.001 (Bonferroni corrected α=05/24=.002). The average growth rate was larger for gestures produced by the participants without visual impairments (r=8.38) compared to the participants with low vision (r=6.53). The τ-C curves grew faster or, equivalently, higher consistency was achieved for smaller τ values for the gestures of participants without visual impairments. Overall, there was 28.4% less consistency in the gestures of the low vision group.

The good fit found between the logistic models and the τ-C curves confirm successful application of the τ-C method to stroke-gestures, where this method has been demonstrated so far for whole-body gestures only [8]. Moreover, our findings consolidate previous results regarding gestures articulated by users with low vision, which are overall less consistent than the same gesture types produced by people without visual impairments [10]. From this perspective, our results constitute a conceptual replication[1] [2] and, thus, contribute to the RepliCHI initiative[2] toward consolidating previous results in HCI, in this case to knowledge regarding touch gesture input behavior for users with low vision.

5 CONCLUSION AND FUTURE WORK

We demonstrated the suitability of the τ-C method for stroke-gesture analysis. We also reported findings about the consistency of gestures articulated by users with low vision on touchscreens, which consolidate previous results and support recommendations from the literature to employ recognizers that are robust to variations in how gestures are articulated by users with low vision [7,10].

[1]Conceptual replications investigate earlier findings by means of different measures, manipulations, and settings [3, p. 3526].
[2]http://www.replichi.com

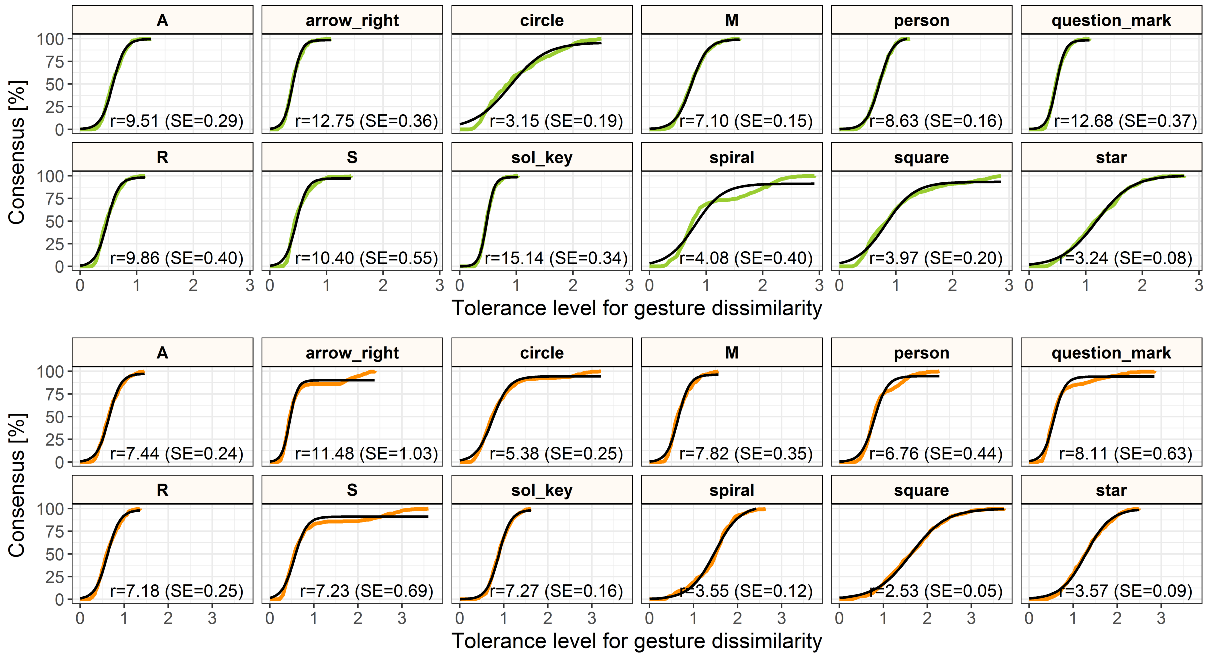

Figure 2: Dissimilarity-consensus growth curves for gestures produced by participants without visual impairments (top) and with low vision (bottom) computed from 6,562 gestures. Logistic models are shown in black, actual data in green and orange.

Future work will apply the τ-C method to other gesture types, such as gestures performed with smart rings [2], and user categories, such as people with motor impairments [11].

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