Emotional Bandwidth: Information Theory Analysis of Affective Response Ratings Using a Continuous Slider

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Abstract. Emotions are an important part of the user experience in human machine interaction. More standardized methods of emotion measurement are required to assist in evaluating and comparing these experiences. This research introduces the concept of Emotional Bandwidth, a psychometric property of self-reported emotion measured through a continuous, quantitative slider. Emotional Bandwidth is illustrated in a videoconference watching case study. The Shannon-Weaver measure of informational entropy was used to quantify the rating usage bandwidth, which relates to the number of levels of emotional rating effectively utilized by participants. Significant differences in rating usage strategy were found, with four groups being identified; across the four experimental blocks, entropy either increased, decreased, remained constant or irregular. Emotional Bandwidth, the information-theoretic analysis of affect ratings collected with a continuous slider, may be used to characterize changes in participants' emotional self-rating during experiments and evaluations.

Keywords: Emotional Bandwidth, Psychometrics, Self-reported Emotion, Information Theory, Affective Responses, Sliders, Evaluation.

1 Introduction

There is increasing focus on affective interfaces and associated emotions such as delight or frustration (eg., [1])., and yet there is no standardized and well-accepted way to characterise participants' emotional responses. This work aims to contribute to a better understanding of self-reported emotion measurement using a continuous slider. Recent work has proposed sliders to measure self-reported emotion [2]. We wish to extend this work, to examine: what are the behavioural characteristics of how people self-report their emotions with continuous sliders?

Rating scales are often used to report participant experiences in tasks. Examples of self-reported scales include the NASA-TLX scale for mental workload assessment and Likert scales of agreement. These are often used to measure subjective effects after an experience. However, drawbacks of this method are that respondents are required to provide a summary of their experience, which may correspond to mode, average or end feelings [3]. Current methods of continuous self-report use sliders [2,4,5] and dials [6]. While continuous sliders have been used quite frequently to

measure affective responses, relatively little attention has been paid to the properties of the ratings that are made using sliders. In this paper we introduce Emotional Bandwidth, an entropy measure of informational complexity of rating scale usage that can reveal important properties of the scale and individual differences in its use. We report the results of a case study where self-reported ratings of affect (satisfaction) were collected using a slider, and where participants' emotional bandwidth demonstrated differences in rating scale usage.

2 Emotion Bandwidth

The capacity of participants' scale usage is one type of behavioural characteristic concerning how people self-report their emotions[7]. Individuals can display varying capacities, which may change over time in response to the stimuli, environment and context. We use the Shannon-Weaver measure of informational entropy to quantify the rating usage bandwidth, which we refer to as Emotional Bandwidth. In this paper, the emotional bandwidth corresponds to the effective number of rating points or levels utilized on the continuous slider scale[1].

Equations 1 and 2 show the informational entropy formula to determine Emotional Bandwidth: the number of levels utilized on the continuous slider scale. In this formula, n refers to the total number of levels on the scale, and p, to the proportion of the total time (x) spent at that level.

$$\text{entropy} = -\sum_{i=1}^{n} p(x_i) \log_2 p(x_i) \quad (\mathbf{1})$$

$$\text{emotional bandwidth} = 2^{\text{entropy}} \quad (\mathbf{2})$$

For example, if a scale has 7 levels and a participant used all levels equally often, the bandwidth score is 7. Those who use the equivalent of two levels would receive a bandwidth of two, regardless of whether those levels are -3 and -2, 1 and 5, or -3 and +3. These patterns are similar in their bandwidth capacity (binary view of emotional state) and that they differ in the strength of the levels reported. Other behavioural characteristics complement bandwidth, such as whether the individual tends to dwell on the positive or negative end of the scale (average), and whether the individual tends to use extreme or neutral levels (variance).

Variance in ratings can be displayed as a histogram, or as an average with standard deviations. A relative advantage of the emotional bandwidth score is that it is a single number, comparable across individuals, and across temporal blocks as participants progress through an experiment or evaluation. Moreover, bandwidth does not depend on the level placement in the scale. In the case mentioned above, the variance of the first individual would be large (moving between -3 and 3) and the second (moving between -1 and 1) would be small, which misses their similar binary capacity.

1 Emotion Bandwidth has been used to refer to the richness of a media channel such as video or text. For e.g., http://www.kapor.com/writing/Emotional-Bandwdith.htm

3 Case Study

Ranjan, Birnholz and Balakrishnan [8] carried out a study to compare the effectiveness of automatic multi-camera capture of a meeting with cinematographic rules versus capture using a professional film crew. Participants watched two 15 minute videos of 3 people discussing a 'survival scenario', where a group chooses the most useful 3 out of 10 tools for survival purposes. The videos were similar in terms of their overall patterns of interaction and artifact usage. A professional crew filmed one video; the other was filmed automatically.

11 participants (7 males, mean age = 26 years) were instructed to pay attention to both the content and the quality of the recording. They were provided with a physical slider to continuously express their satisfaction (on a 7 point scale that varied from -3 to +3, with a neutral (0) center). Participants were instructed to move the slider as often as necessary to best represent their affective feelings of satisfaction with the video coverage. A small window on the screen showed the numerical slider position.

The information complexity was calculated for each participant in terms of bits, based on the frequencies with which each point on the rating scale was used. Roughly 30 minutes of data was collected for each participant with slider positions being sampled at a rate of once per second for a total of about 1800 slider position assessments per participant. Data from one participant (ID = 3) was removed because it was incomplete. If a level was dwelled on for one second or less, it was treated as an intermediate level, and not included in the bandwidth calculations.

For number of bits H, the equivalent number of rating points used was then calculated as 2^H. The corresponding rating bandwidths had an average of 5.44 (std dev =.77). These rating bandwidths are interpreted as the effective number of rating points used by each participant. For this sample, they ranged from just under 4.2 rating points to just over 6.5 rating points.

Blocks. The consistency of rating scale usage was then assessed by dividing the data into four blocks each of approximately 7.5 minutes in duration. While some participants showed a relatively constant level of rating bandwidth across the four blocks, others show more variability. Five participants were selected as having relatively constant rating bandwidth across blocks. Based on visual inspection of the data, we classified remaining participants into three groups: two participants with a decreasing trend across the blocks, one with an increasing trend, and three with a blip (i.e., a temporary drop in one of the blocks followed by recovery).

We carried out repeated measures ANOVA to examine the interaction between blocks, and found a significant interaction effect of subject group and block on rating bandwidths ($F[3,7]=12.74$, $p<.005$). Using Mauchly's test, sphericity was not found to be violated.

This statistic should be interpreted cautiously since the groups were extracted from visual inspection of the data. This result suggest that the type of information theoretic analysis used here on slider data can be used to capture meaningful differences between participants in terms of how rating scales are used. Figure 1 shows the average rating bandwidths across the blocks for the four inferred groups.

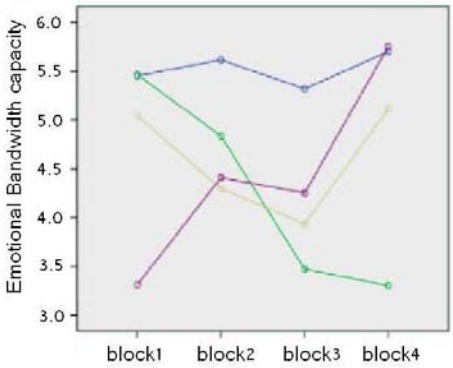

Fig. 1. Average rating bandwidths across four blocks for four groups of participants

Conclusions. Continuous sliders collect individual's impressions of their affective state. We contribute a novel application of information theory to characterize those ratings: emotional bandwidth. Emotional bandwidth is a psychometric property that represents participants' capacity, or the number of scale rating points that he or she is effectively utilizing. A case study showed variations in emotional bandwidth that distinguished different styles of rating scale usage. The present work is a first step in terms of research on the use of continuous sliders to collect detailed information on participants' motivation, affect, and capacity during experiments and evaluations.

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