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Incorporating Response Confidence into Adaptive Methods for Threshold Estimation

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In psychophysical studies of discrimination, thresholds are commonly estimated by (nonparametric, fixed-step-size) adaptive methods using a binary response format. However, it can sometimes be challenging for participants to give a dichotomous response. To resolve the issue, scholars have suggested adding more response categories to the algorithm (Kaernbach, 2001; Klein, 2001). However, Hsu and Chin (2014) argued that their extension has some limitations. Following Hsu and Chin (2014), we proposed an alternative framework to incorporate response confidence into existing adaptive methods for Yes/No tasks. In particular, we introduced the concept of a "cut-off," thereby expanding the meaning of psychometric functions to psychometric surfaces. We performed simulations to investigate the feasibility of the framework. We considered three adaptive methods, namely Derman's Up-Down (DUD) method (Derman, 1957), the Biased Coin Design (BCD) (Durham & Flournoy, 1995), and the Weighted Up-Down (WUD) method (Kaernbach, 1991). Setting 0.75 as the target probability for the threshold, we systematically manipulated the initial value, step size, cut-off, and number of trials to examine their impact on the threshold estimation performance of the three adaptive methods. Our simulation results showed that the proposed framework is applicable in general and that WUD and BCD performed slightly better than DUD. We also extended the framework to the Same/Different task, where the psychometric function is not monotonically increasing. We tackled this issue by providing mappings between the response confidence scales of the Same/Different task and the Yes/No task. Doing this enables us to obtain a transformed psychometric function that satisfies the monotonicity property, and thus the aforementioned framework can be readily applied to the Same/Different task.

Keywords: *response confidence, adaptive methods, threshold estimation*

In psychophysical studies of discrimination, thresholds are commonly estimated by (nonparametric, fixed-step-size) adaptive methods using a binary response format. However, it can sometimes be challenging for participants to give a dichotomous response. To resolve the issue, scholars have suggested adding more response categories to the algorithm (Kaernbach, 2001; Klein, 2001). However, Hsu and Chin (2014) argued that their extension, which assumes unbiased confidence levels and symmetrical weights for positive and negative response categories, may not always be supported by empirical data.

To overcome this problem, following Hsu and Chin (2014), we propose an alternative framework to incorporate response confidence into existing adaptive methods for Yes/No tasks. In particular, we introduce the concept of a "cut-off," thereby expanding the meaning of psychometric functions to psychometric surfaces. Specifically, on each trial, the participant responds by indicating her confidence level on a continuous scale. A predetermined cut-off, which the participant is unaware of, is used to decide whether the response is positive or negative, and the target stimulus on the next trial is determined by the algorithm specified in the original adaptive method for a given response criterion. Adding response confidence to the original estimation framework is tantamount to introducing one more dimension to the psychometric function. To illustrate, Figure 1 displays a three-dimensional graph of the psychometric surface. The three solid gray curves are the distributions for response confidence at three intensity levels. The dashed curve shows the relationship between the mean confidence level and signal intensity. Note that traditional adaptive methods can be regarded as a special case in which the cut-off is set in the middle of the response confidence scale.

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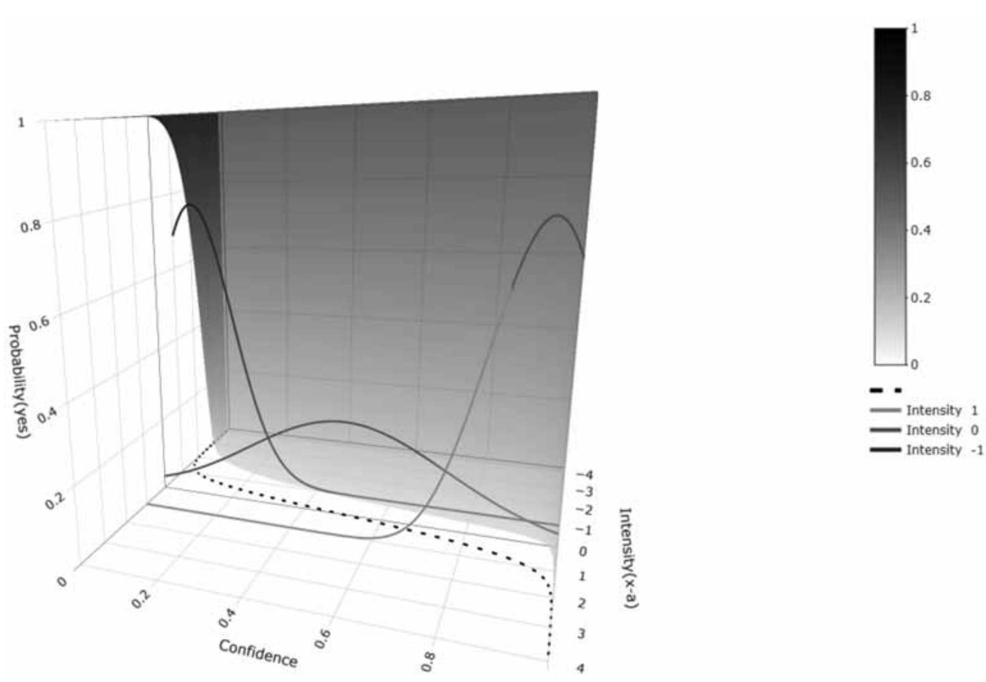
We also extended the framework to the Same/Different task, a commonly used experimental paradigm for the study of categorical perception. Unlike the Yes/No task, the psychometric function of the Same/Different task is not monotonically increasing. We tackled this issue by providing mappings between the response confidence scales of the Same/Different task and the Yes/No task. To illustrate, let us assume that the response confidence scale is between 0 and 1 for the Yes/No task, with "great confidence" represented at both ends. Furthermore, 0.5 represents "great uncertainty," a situation that is most likely to occur when the comparison stimulusand the standard stimulusare (approximately) equal. For the Same/Different task, a response confidence of 1 indicates "great confidence" and 0 "low confidence" in answering "same."

We consider two situations, $x \geq a$ and $x < a$. Figure

Figure 1

A three-dimensional graph for the psychometric surface showing the relationship of probability, response confidence, and stimulus intensity



2(a) shows the ranges of the mappings between the response confidence (R_n^*) in the Same/Different task and the response confidence (R_n) in the Yes/No task. Figure 2(b) further specifies that the respective mappings are linear. These mappings enables us to obtain a transformed psychometric function that satisfies the monotonicity property, and thus the aforementioned framework can be readily applied to the Same/Different task.

Figure 2

The relationship between the response confidence (R_n^*) in the Same/Different task and the response confidence (R_n) in the Yes/No task