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Electrophysiological correlates of adjustment process in anchoring effects

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ABSTRACT

Anchoring is a judgmental bias that final judgments are assimilated toward the starting point of the judge's deliberations. The anchoring-and-adjustment heuristic holds that anchoring bias is caused by insufficient adjustment. With the manipulation of some subjective factors, previous research found that anchoring is an effortful process. However, there is little evidence supporting that the effortful process is an adjustment process. In the present work, number accuracy was introduced as an objective factor which involves in an adjustment process. An event-related brain potential (ERP) experiment on young normal subjects examined the impact of number accuracy on anchoring processes responding to anchors which were generated by subjects themselves. A dot-image paradigm was firstly employed to explore anchoring effects. Behavioral results found less accurate anchors which determined a coarser mental scale diminished the anchoring biases responding to self-generated anchors. A positive deflection at 250–800 ms after target onset can be taken as a direct electrophysiological evidence of the adjustment process, whose amplitude was more positive on more accurate anchors condition. The present results further support that people adjust upwards or downwards on a mental scale from the self-generated anchor, which is consistent with the adjustment heuristics.

Anchoring is a robust and pervasive judgmental bias: final judgments and behavior are assimilated into a previous anchor value (even if the value is arbitrary). In a wheel of fortune study, the participants were asked to decide if the percentage of African countries in the United Nations was above or below 65 or 10 that was randomly generated by spinning the wheel of fortune. Then the participants estimated the absolute percentage. Although it may seem unlikely, the evidence is that such anchors have an effect: in fact, groups who received larger numbers determined by a wheel of fortune gave higher estimates than groups who received lower numbers, demonstrating that irrelevant anchors influenced these estimates [22].

Previous anchoring research has suggested and demonstrated that there are distinct anchoring effects produced by two mechanisms. The anchor's source is an important feature that makes possible to distinguish two anchoring processes [6]. It is assumed that the externally provided anchor which is presented by the experimenter in a comparative question might cause an accessibility process [13,20]. For example, when people were asked, "Did Gandhi live to be more or less than 79 years old?" as an anchor question, people wonder if Gandhi lived a long life. Because people instinctively think about hypotheses by confirming them [11,19], the accessibility of the long-lived information about Gandhi (anchor-consistent) disproportionately increased. Since such accessible knowledge is likely to influence a judgment at hand [8], a biased estimation value was retrieved as a final estimate. The self-generated anchor which is generated by participants is suggested to produce an adjustment process [4–6]. For example, participants were asked, "In what year was George Washington elected President of the United States?" Most people knew the year the United States declared its independence, which then acted as an anchor for them to estimate when George Washington was elected President [6]. It is assumed that the self-generated anchor might cause an adjustment process, and the anchor serves as a starting point. The adjustment was always insufficient and stopped at the edge of a plausible range, leaving final estimation close to the anchor [5,18]. Manipulations that should thwart a person's ability to engage in effortful process, such as time pressure and attentional load, were found to diminish the anchoring bias caused by self-generated anchors only [4,14], so were manipulations that should increase a person's willingness to engage in effortful adjustment, such as incentives for accuracy or forewarnings [1,22,23]. Researchers thus interpret anchoring responding to external anchors as an effortless process and anchoring responding to self-generated anchors as an effortful process

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[4,7]. Till now, efforts to identify the mechanism of accessibility involved in responses to externally provided anchors have yielded direct evidence by studies showing a reaction time advantage to anchor-consistent words in a lexical decision task after an anchoring task [15]. The mechanism of adjustment, which is assumed to be involved in responses to self-generated anchors, still calls for further supports.

With this research, we attempt to advance previous work in at least two important ways. Firstly, the present research is to investigate whether an adjustment process is involved in the anchoring process responding to self-generated anchors. The accuracy of anchor numbers will be introduced as a factor to affect the adjustment process. Researchers suggest that people might adjust upwards or downwards by “sliding” along an internal scale or by “jumping” several graduations from the anchor until reaching a satisfactory estimate [6]. Thus, the mental scale might be involved in an adjustment process. It was found that both the number size and the external number accuracy could determine the coarseness of mental scale [2,12,21]. The scale is finer-grained with more categories when the external numbers are accurate to ones' place such as 11, 21, etc., while the scale is coarser-grained with fewer categories if accurate to tens' place such as 10, 20, etc. [21]. We manipulated the anchors accuracy to investigate whether the coarseness of mental scale influence the process responding to self-generated anchors. When less accurate anchors are represented as a coarser internal line with at least a “10” graduation, e.g., 10, 20, 50, the adjustment upwards one graduation adds 10 to the initial anchor value, resulting in 20, 30, 60. While more accurate anchors on a finer scale with a “1” graduation, e.g., 11, 21, 51, would lead a more difficult operation, the adjustment upwards one graduation adds 1 to the initial anchor value, resulting in 12, 22, 52. We predicted more accurate anchors would cause a larger anchoring bias and lead a more difficult operation.

Secondly, previous research on anchoring effects mainly used questionnaires to measure anchoring effects. To our knowledge, only an alpha-band activity in electroencephalogram (EEG) recordings was collected to explore the comparative process. Electrocortical changes closely associated with reduced mental effort demonstrated that comparative information processing may reduce mental effort in judgment tasks [10]. We propose to employ event-related potential (ERP) technique to investigate the neural correlate of the adjustment process engaged in anchoring effects responding to self-generated anchors. Since this is a first attempt to explore the neural correlates of anchoring effects using ERP technique, we could only predict that processes caused by two kinds of anchors would be differentiated in the ERP pattern.

We designed a novel paradigm to simulate a self-generated anchors situation in an ERP laboratory. First, participants were asked to complete a study task to learn the quantity of dots in some dot-images. In the formal experiment, the known dot-images serving as self-generated anchors were presented before target images. The task for participants is to estimate the quantity of the dots in target dot-images.

Twenty subjects from Beijing Normal University were paid for participation. All participants gave written informed consent were right-handed, and had normal or correct to normal vision. The average age was 20.6 ± 2.1-years old. None of the participants had any neurological impairment. Two participants quitted the experiment because of procedure error. One participant was excluded because he missed to report the estimates verbally in one block. Two participants were excluded because of their low-rates of artifact-free trials. Finally, only 15 subjects' data (7 females) was analyzed.

Six monochrome pictures with a circle full of dots were used as targets for participants to estimate. The relationship between the cue number and target picture was manipulated by a 2 (anchor value: higher vs. lower) × 2 (anchor accuracy: more accurate vs. less accurate) fully within subject design.

Table 1
Number of dots in anchor image and target image in the 24 experimental items

Target	More accurate lower anchor	More accurate higher anchor	Less accurate lower anchor	Less accurate higher anchor
40	18	62	20	60
90	62	119	60	120
180	119	242	120	240
400	242	557	240	560
872	557	1187	560	1190
602	18	1187	20	1190

Two known distinct dot-images were set for one target circle as higher anchor and lower anchor. Accordingly, 12 images in one accuracy condition should be concluded. However, it seems too difficult for participants to learn the number of dots in a study task. In order to make the learning task easier, we adjusted the density of the circle so that one anchor circle can serve as either the high anchor of one target or the low anchor of another target, which finally yielded seven circles in one accuracy condition. The discrepancy between lower anchor value and target value was ensured to be identical to that between higher anchor value and target value. Anchors with integers correct to tens' place were classified as more accurate condition; and anchors with integers correct to ones' place were classified as less accurate condition. Thus, 24 experimental items in four conditions were yielded (see Table 1).

The fixations in center of cue circles were red and those in target circles were white. To allow for enough trials for the ERP recording, each problem was presented 10 times. In the end, there were 240 trials for the participants to process. Trials within different accuracies were presented in separate blocks, which resulted in two blocks. Higher anchors or lower anchors were randomly presented within a block. The order of two blocks was counterbalanced over all participants. We used an E-Prime software to present the stimuli.

There was a study task before the formal experiment. The participants were first told the number of dots in each dot-image. As one image appeared, they reported the quantity. All the fixations in the center of circles were red. The study phase would not stop until they could report the correct answer to each item within 1500 ms.

In the formal experiment, participants sat on a comfortable chair in front of a computer screen located at eye level at a distance of 75 cm. The target circles were subtended a visual angle of 8.6°. Instructions reminded the participant estimated the dots in target images by the cue images, and the estimates emphasized both speed and accuracy. The procedure of one trial was illustrated in Fig. 1. On one trial, a fixation cross was presented in the center of the screen for 300 ms, and then the anchor image was presented. As soon as participant remembered the quantity of this known circle, he was instructed to press the “Space” key, which confirmed that the participant generated the anchors himself. After a blank screen for randomized between 200 ms and 400 ms, the target picture was presented. The average RT from the behavioral pretest helped to determine the duration of target picture as 1500 ms in ERP experiment. Then a prompt appeared in the center of the screen, which cued participants to verbally report the estimate of the target picture, visible for 1000 ms. The intertrial time was 1500 ms after the reporting prompt. The participant's verbal report was audiorecorded by a digital recorder and later carefully transcribed manually. The experiment lasted approximately 40 min overall.

ERPs were recorded and analyzed with SCAN 4.3 software (NeuroScan Inc.). The EEG was recorded from 64 scalp sites using silver chloride electrodes mounted in an elastic cap (NeuroScan Inc.), with the reference on the left mastoids. The vertical electrooculogram (EOG) was recorded with electrodes placed above and below

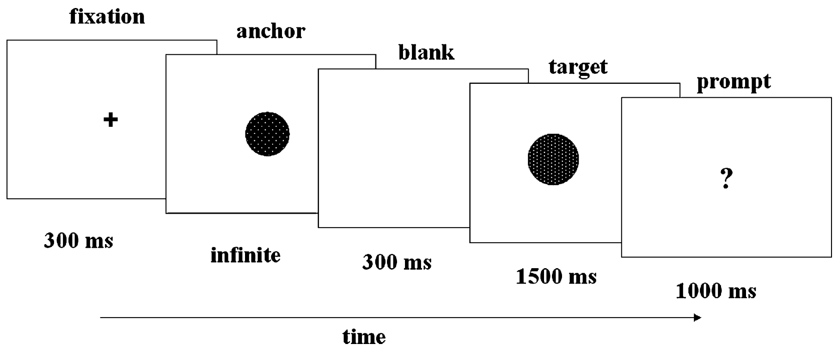

Fig. 1. Illustration of the estimation task.

the left eye. The horizontal electrooculogram was recorded with electrodes placed at the outer canthi of both eyes. All interelectrode impedance was kept below 5 kΩ. Signals were amplified with 0.05–100 Hz bandpass filter and digitized at 500 Hz. Offline, ocular artifacts were removed from the EEG signal using a regression procedure implemented in the Neuroscan software. The continuous EEG data was segmented into epochs from 200 ms pretarget (i.e., 200 ms before the onset of target picture) until 1000 ms poststimulus. The 200 ms pretarget served as the baseline. EEG was detrended and baseline-corrected. Trials with various artifacts were rejected, with a criterion of ±80 μV.

The remaining trials were averaged for each condition separately for each subject. The valid epochs included for averaging is 47.4 ± 1.8 for more accurate lower anchor, 47.2 ± 1.7 for more accurate higher anchor, 48.3 ± 2.3 for more accurate lower anchor, and 48.1 ± 2 for more accurate lower anchor. The grand average was obtained by averaging across the subjects' averages separately for each arithmetic operation. Mean amplitudes were measured in time window of 250–350 ms and 450–800 ms after stimulus onset. Data analysis involved repeated measure analysis of variance (ANOVA) with factors anchor value (higher vs. lower), accuracy (more accurate vs. less accurate), and two factors that index scalp topography: laterality (left, midline and right), anterior–posterior (frontal, central, centro-parietal, parietal and parietal–occipital). Fifteen electrode sites were analyzed: Fz, Cz, CPz, Pz, POz, F3, C3, CP3, P3, PO5, F4, C4, CP4, P4, and PO6. The Greenhouse–Geisser correction was used to compensate for sphericity violations.

The participants' estimates were transformed into *z*-scores using the mean and standard deviation. Negative numbers represent estimates that are below the mean; positive numbers represent estimates that are above the mean. Fig. 2 shows participants' estimates in *z*-scores. A 2 × 2 ANOVA with repeated measure revealed a significant main effect of anchor ($F(1,14) = 176.67$, $p < .05$), indicating a sizable anchoring effect in this paradigm. The predicted interaction between anchor value and accuracy yielded ($F(1,14) = 33.02$, $p < .05$). A simple effect analysis revealed that estimates after high anchors in the more accurate condition ($M = 0.51$, S.D. = 0.33) were more than those in the less accurate condition ($M = 0.34$, S.D. = 0.36), $F(1,14) = 11.44$, $p < .05$; estimates after lower anchor in the more accurate condition ($M = -0.62$, S.D. = 0.27), by contraries, were less than in the less accurate condition ($M = -0.33$, S.D. = 0.44), $F(1,14) = 12.70$, $p < .05$.

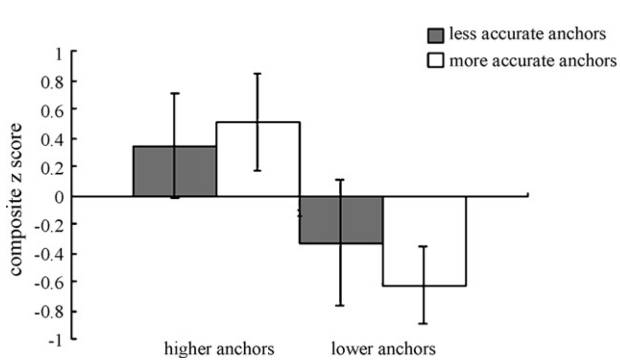

Fig. 2. Average estimates (in *z*-scores) in the four conditions. Means ± S.D.

Grand average ERPs in four conditions are shown in Fig. 3. There is a negative outgoing called N2 temporarily and a LPC in the waveform.

A repeated measures ANOVAs on the mean amplitudes of N2 showed a significant main effect of accuracy ($F(1,14) = 7.90$, $p < .05$), and a marginal significant interaction of accuracy × anterior–posterior ($F(4,56) = 3.16$, $p = .058$). A simple effect analysis showed that the mean amplitude of N2 was more negative in less accurate condition than that in more accurate condition significantly at frontal ($F(1,14) = 13.41$, $p < .05$; 0.82 ± 0.73 vs. 1.72 ± 0.70 μV), central ($F(1,14) = 10.85$, $p < .05$; 1.83 ± 0.74 vs. 2.75 ± 0.73 μV), and centro-parietal locations ($F(1,14) = 7.70$, $p < .05$; 3.08 ± 0.71 vs.3.91 ± 0.67 μV). ANOVA with repeated measures of mean amplitude of LPC revealed a significant main effect of accuracy ($F(1,14) = 7.10$, $p < .05$), and a marginally significant interaction of accuracy × anterior–posterior ($F(4,56) = 2.60$, $p = .08$). A simple effect analysis revealed that the LPC elicited by more accurate anchors was more positive than that by less accurate anchors significantly at frontal ($F(1,14) = 4.93$, $p = .05$; 1.49 ± 0.72 vs. 0.42 ± 0.57 μV), central ($F(1,14) = 9.31$, $p < .05$; 3.48 ± 0.77 vs. 2.16 ± 0.71 μV), centro-parietal ($F(1,14) = 9.40$, $p < .05$; 4.65 ± 0.73 vs. 3.37 ± 0.69 μV) locations.

In this study, we introduced a new paradigm to obtain anchoring effects for EEG recording. Rather than estimate a target referring to general knowledge, the task in our experiment was to estimate the physical property of an object presented visually. Although each experimental item was presented 10 times, the behavioral results still demonstrated a sizable anchoring effect, which indicated the reliability of this paradigm. As predicted, the behavioral results showed that less accurate anchors diminished anchoring bias in response to self-generated anchors.

The behavioral results are consistent with the adjustment account. Less accurate anchors determine a coarser-scale with fewer categories, adjusting one graduation upwards or downwards means adding or subtracting a greater amount than that on a finer-scale, and caused the anchors to be more skewed. However, the accessibility account could not interpret such behavioral results. The accessibility account holds that anchoring effects are driven by excessively accessible anchor-consistent information. In the current study, more accurate anchors and less accurate anchors are similar numbers, which indicate similar anchor-consistent information. Consequently, anchors accuracy should not influence the size of anchoring bias. Given the mental scale was only involved

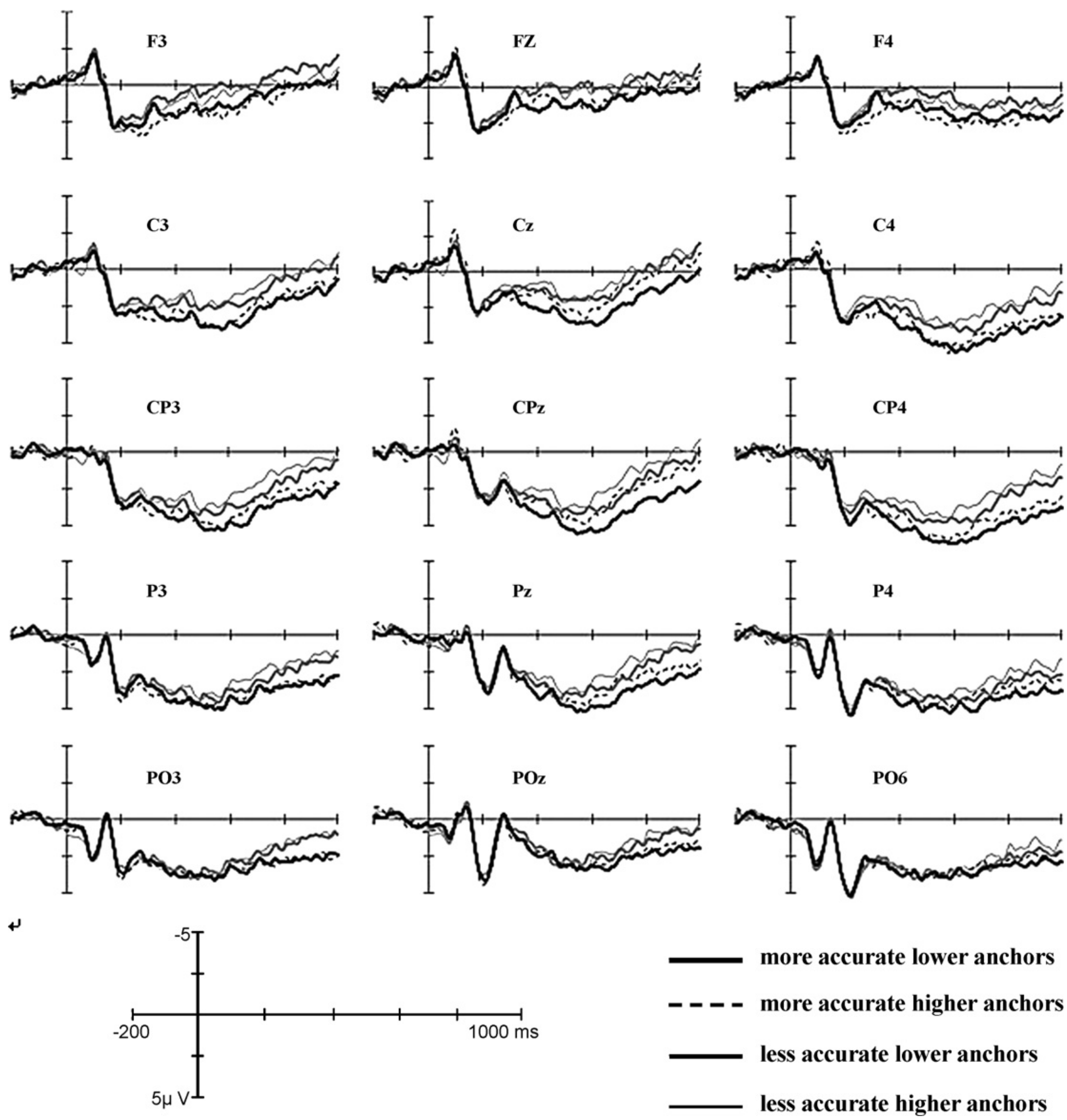

Fig. 3. Grand average waveforms for ERPs elicited in the four conditions, time lock to target onset in four conditions. Negativity is plotted upwards.

in the adjustment process, the results support that an adjustment process is a possible process responding to self-generated anchors.

The ERPs demonstrated that the N2 in the window of 250–450 ms had a similar modulation associated with accuracy as the LPC at frontal, central, and centro-parietal locations: the more accurate the anchors, the more positive the amplitude.

The ERPs suggest anchor accuracy influences the anchoring process responding to self-generated anchors. Self-generated anchors, different from externally provided anchors, are known – from the beginning – to be an impossible potential answer to target question. In the present study, a study task prior to formal experiment ensures participants knowledgeable of some dot-images. In the formal experiment, targets are new dot-images. Obviously, participants do not think that number of anchor dot-image is the possible number to target dot-images. Without an evaluation, an accessibility process could not be activated. So the ERPs cannot be explained by an accessibility mechanism. Then, what is the mechanism of anchoring effects responding to self-generated anchors. It is noteworthy that self-generated anchors are known to be incorrect but close to the correct answer. People thus adjust upwards or downwards from the anchor value to a satisfactory answer, which was similar to addition or subtraction. In the current experimental task, participants add some if the target dot-image is denser than the anchor dot-image. Conversely, they subtract some when dealing with a sparser target dot-image. Addition and subtraction on different scales involved different problem difficulty and solution size, which are potential factors in comparisons of cognitive arithmetic tasks. The arithmetic operation is more difficult in the more accurate condition (e.g., 123 ± 8) than that in the less accurate condition (e.g., 120 ± 80). We thus infer that the voltage differences in N2 and the LPC were associated with problem difficulty. Previous research has reported that a late positive wave from 250 ms to 800 ms poststimuli was functionally related to exact mental arithmetical calculation [3,9]. The amplitude difference in a late positive wave in 250–800 ms was a function of the problem difficulty: the more difficult the problem, the larger the voltage [16,17]. During that positive wave related to arithmetical processing, there was also a similar negative ongoing in the window of 300–500 ms in spite of the positive voltage [16]. In the present experiment, N2 had the same scalp distribution and modulations related to accuracy as LPC. We suggest that the N2 and the LPC should be elicited by anchors accuracy, underlying the same psychological component: mental calculation. As a consequence, a positive deflection can be taken as a direct electrophysiological correlate of the process responding to self-generated anchors.

Both behavioral results and ERP results demonstrate an impact of anchor accuracy. Further, the ERP results demonstrated that a mental calculation might be involved in the process responding to self-generated anchors. Since the internal scale whose coarseness is determined by accuracy of anchors is involved in current process, we suggest that adjustment is the possible mechanism for the anchoring effect caused by self-generated anchors.

In summary, this study showed less accurate anchors which determined a coarse mental scale diminished anchoring effects responding to self-generated anchors. A positive deflection in 250–800 ms poststimulus whose amplitude was modulated by the accuracy of anchors was suggested to be related to anchoring process responding to self-generated anchors, which provided further evidence supporting that adjustment might be the possible mechanism underlying anchoring caused by self-generated anchors.

Some questions still remain. Since the present paradigm employed target questions related to physical property of given objects, the findings need further evidence from research on questions in real life. Moreover, in real life, people who have enough knowledge to generate an anchor by themselves often have to deal with another externally provided anchor at the same time. What will the process like in this case? In addition, due to the limited spatial resolution of the ERP technique, the source of anchoring effects is still uncertain. We hope further research will resolve these questions.

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