Abstract:

Research on effort and motivation commonly measures how the sympathetic branch of the autonomic nervous system affects the cardiovascular system. The cardiac pre-ejection period (PEP), assessed via impedance cardiography, is a widely-used sympathetic outcome, but assessing PEP requires identifying subtle points on cardiac waveforms. The present research examined the value of the RZ interval (RZ), which has recently been proposed as a measure of sympathetic activity, for effort research. Also known as the initial systolic time interval (ISTI), RZ is the time (in ms) between the ECG R peak and the dZ/dt Z peak. Unlike PEP, RZ involves salient waveform points that are easily and reliably identified. Data from three experiments evaluated the suitability of RZ for effort research and compared it to a popular, automated PEP method. Participants completed a standard mental effort task in which correct responses earned a small amount of money. As expected, incentives significantly affected PEP and RZ in all three experiments. PEP and RZ were highly correlated (all $rs \geq .89$), and RZ consistently yielded a larger effect size than PEP. A quantitative synthesis of the experiments indicated that the effect size of RZ's response to incentives (Hedges's $g = .387$ [.248, .527]) was roughly 20% larger than PEP's effect size ($g = .323$ [.185, .461]). RZ thus appears promising for future research on sympathetic aspects of effort-related cardiac activity.

Keywords: effort | pre-ejection period | RZ | impedance cardiography | motivation | incentives | initial systolic time interval

Running head: RZ INTERVAL

Evaluating the RZ Interval and the Pre-ejection Period as Impedance Cardiography Measures of Effort-Related Cardiac Sympathetic Activity

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Abstract

Research on effort and motivation commonly measures how the sympathetic branch of the autonomic nervous system affects the cardiovascular system. The cardiac pre-ejection period (PEP), assessed via impedance cardiography, is a widely-used sympathetic outcome, but assessing PEP requires identifying subtle points on cardiac waveforms. The present research examined the value of the RZ interval (RZ), which has recently been proposed as a measure of sympathetic activity, for effort research. Also known as the initial systolic time interval (ISTI), RZ is the time (in ms) between the ECG R peak and the dZ/dt Z peak. Unlike PEP, RZ involves salient waveform points that are easily and reliably identified. Data from three experiments evaluated the suitability of RZ for effort research and compared it to a popular, automated PEP method. Participants completed a standard mental effort task in which correct responses earned a small amount of money. As expected, incentives significantly affected PEP and RZ in all three experiments. PEP and RZ were highly correlated (all *r*s $\geq .89$), and RZ consistently yielded a larger effect size than PEP. A quantitative synthesis of the experiments indicated that the effect size of RZ's response to incentives (Hedges's $g = .387$ [.248, .527]) was roughly 20% larger than PEP's effect size ($g = .323$ [.185, .461]). RZ thus appears promising for future research on sympathetic aspects of effort-related cardiac activity.

Keywords: effort; pre-ejection period; RZ; impedance cardiography; motivation; incentives; initial systolic time interval

Evaluating the RZ Interval and the Pre-ejection Period as Impedance Cardiography Measures of Effort-Related Cardiac Sympathetic Activity

Influenced by Obrist's (1982) active coping model, research on the psychophysiology of effort has traditionally emphasized autonomic outcomes that reflect the sympathetic branch's beta-adrenergic impact on the heart (Gendolla, Wright, & Richter, 2012). Early work consistently found that systolic blood pressure (SBP) was sensitive to factors important to effort, such as the difficulty of a task and the value of goals and incentives (Wright, 1996), and SBP continues to be prominent (e.g., Silvia, 2012; Barreto, Wright, Krubinski, Molzof, & Hur, 2015). Recent work has emphasized the cardiac pre-ejection period (PEP; Kelsey, 2012), a systolic time interval typically assessed via impedance cardiography. PEP is the time in ms between the onset of depolarization (the ECG Q point) and the onset of ejection, defined as the opening of the aortic valve (the dZ/dt B point; see Figure 1).

Impedance-based assessment of PEP has been a fruitful addition to mental effort research. Nevertheless, PEP has some longstanding assessment issues that remain unresolved (Mendes, 2009; Sherwood et al., 1990). The Q and B points that define PEP can be subtle and hard to pinpoint because of individual-differences in cardiac waveforms and the many factors that can degrade cardiac signals measured non-invasively with skin electrodes (Berntson, Lozano, Chen, & Cacioppo, 2004; Cybulski, 2011). As a result, researchers have developed alternative methods for approximating and estimating the points' locations. These approximations facilitate scoring for large-sample projects and avoid the need to exclude large portions of otherwise unscorable data.

For the ECG Q point, for example, researchers have suggested using the onset of the Q wave, the peak of the Q wave, the onset of the R wave, or a fixed constant (e.g., 40 or 48 ms before R) to identify Q (Berntson et al., 2004; Sherwood et al., 1990; van Lien, Schutte, Meijer, & de Geus, 2013). Others have suggested abandoning the Q point entirely and using the peak of the R wave instead (Seery, Kondrak, Streamer, Saltsman, & Lamarche, 2016). For the B point, several identification methods have been proposed, such as using the second and third derivatives of the dZ/dt signal, the dZ/dt zero-crossing point, or the primary rapid-rise in dZ/dt (Árbol et al., 2017; Ermishkin, Kolesnikov, & Lukoshkova, 2014; Forouzanfar et al., in press; Lozano et al., 2007; Sherwood et al., 1990).

One prominent method, developed by Lozano et al. (2007), estimates the likely B point as a regression function of the distance between the ECG R point and the dZ/dt Z point. Their research found that 93% of the between-person variance in the distance between R and B could be captured by a simple linear model (RB = RZ*.55 + 4.45), which in practice (e.g., Mindware's IMP software) is commonly implemented as 55% of the RZ interval plus 4 ms. This slope/intercept method is probably the most widely-used B-point approximation method in contemporary research.

PEP is the most prominent impedance metric of sympathetic activity, but additional metrics have been developed. The complexity of identifying PEP's points suggests that the validity of these other metrics deserves a closer look. The RZ interval—also known as the initial systolic time interval (ISTI) and as RZ—is an old outcome (e.g., Wilde et al., 1981) but has recently attracted attention as a promising measure of contractility (Cybulski, 2011; Meijer, Boesveldt, Elbertse, & Berendse, 2008; Van Eijnatten, van Rijssel, Peters, Verdaasdonk, & Meijer, 2014). RZ is the time in ms between the ECG R peak and the dZ/dt Z peak (see Figure 1). Z is the point during ejection in which the aortic arch has its maximal diameter (Van Eijnatten et al., 2014), so RZ can be viewed as the time between the heart's peak electrical activity and its peak mechanical activity (Meijer et al., 2008).

RZ has been used for decades in impedance cardiography research. Many studies have shown that RZ behaves similarly to PEP, which isn't unsurprising in light of their overlap in the cardiac cycle (see Figure 1). For example, both PEP and RZ respond similarly to exercise (Meijer et al., 2008; Wilde et al., 1981), stress (Kelsey & Guethlein, 1990), dobutamine infusion (van der Meer, Noordegraaf, Bax, Kamp, & de Vries, 1999), and changes in posture and activity levels (van Lien et al., 2013). In their analysis of RZ/ISTI and the slope/intercept approximation, van Lien et al. (2013, p. 68) noted:

> Changes in cardiac contractility are reflected not only in the time it takes the left ventricle to build up sufficient force to open the aortic valve (reflected in the B-point) but also in the time it takes to reach peak ventricular ejection (dZ/dt-min peak), which is reflected by the ISTI. Hence the information between PEP and ISTI strongly overlaps empirically and theoretically, and ISTI might itself be considered as a measure of cardiac sympathetic control based on physiological grounds.

One virtue of RZ is that it probably contains less measurement error. PEP and RZ are difference scores—the difference, in ms, between two points in the cardiac cycle—and the reliability of a difference score stems in part from the reliability of the two primary scores (Rogosa & Willett, 1983). Errors in measuring single waveform landmarks—such as Q, B, R, and Z—will thus result in increased error in the resulting difference scores. The identification of the subtle Q and B points for PEP probably involves more error than RZ, which is defined by two salient peaks that are easily identified with automated methods (Meijer et al., 2008).

The present research, in the spirit of calls for additional validity testing (van Lien et al., 2013), evaluated the suitability of RZ as a marker of effort-related sympathetic activity in contexts calling for mental effort. As noted earlier, SBP and PEP are popular outcomes in this area. An additional, complementary measure of contractility would be valuable, particularly for ambulatory impedance methods (Sperry, Kwapil, Eddington, & Silvia, 2018), which yield noisier signals (Cybulski, 2011) in which Q and B are typically less apparent (van Lien et al., 2013). We used a prototypical incentive paradigm: exerting effort to attain cash payment. Effects of incentives on PEP in appetitive effort paradigms are well-established (e.g., Richter, 2012; Richter, Friedrich, & Gendolla, 2008; Richter & Gendolla, 2009), so these classic paradigms are useful for comparing RZ and PEP. We assessed PEP using the Lozano et al. (2007) slope/intercept approach, both because it is ubiquitous in modern research and because a conceptual replication of van Lien et al.'s (2013) findings would contribute to the growth of knowledge about RZ/ISTI.

In three experiments, participants completed a reward responsiveness task that allowed them to work at their own pace and accumulate cash rewards for each correct response. Baseline-to-task change in PEP and RZ was assessed, and the relative influence of incentives on each cardiac outcome was evaluated. Studies 1 and 2 were re-analyses of recent effort studies that did not initially compare PEP and RZ (Harper, Eddington, & Silvia, 2016; Harper, Silvia, Eddington, Sperry, & Kwapil, 2018); the data from Study 3 have not been previously analyzed or reported[1]. We conclude with a meta-analytic synthesis of the 3 experiments to summarize the relative effects of PEP and RZ in response to incentives.

Study 1

In Study 1, we used a standard paradigm from the mental effort literature to evaluate the effects of incentives on effort-related cardiac activity. Participants worked on a self-paced task in which each correct response earned a small amount of money. In such circumstances (Brehm & Self, 1989; Wright, 2008), the intensity of effort is a function of the value of the incentive, and many studies find that measures of beta-adrenergic sympathetic influences on the heart increase when incentives are provided in such tasks (Richter, 2012). Both RZ and PEP, assessed via the Lozano et al. (2007) method, were measured so that we could evaluate how highly they correlate and whether one has a larger effect size.

Method

Participants and Design

A sample of 51 adults (18 men, 33 women) took part and received credit toward a research option in a psychology class. The data come from a broader study on personality traits

[1] Specifically, in Study 1, the parity task data were reported as part of a study of how conscientiousness predicts effort in response to incentives (Harper et al., 2018), and in Study 2, the parity task data were reported as part of a study on perfectionism and mental effort (Harper et al., 2016). In Study 3, the parity task data have not been previously analyzed or reported. For the two re-analyses, the degrees of freedom may vary slightly because of differences in missing data associated with the different variables of interest.

and mental effort (Harper et al., 2018). The sample had a mean age of 19.38 years (*SD* = 2.02 years, range 18 to 28). According to self-reported race and ethnicity, the sample was diverse: 48% European American, 34% African American, 20% Hispanic/Latino, 6% Native American, and 4% Asian American. (People could choose multiple categories or decline to pick any.)

The experimental design had one within-person independent variable: *incentive value* (1 cent vs 5 cents). There were two-between person independent variables: counterbalanced incentive order (1 cent first vs 5 cents first), and stimulus set (set 1 first or last). People were randomly assigned to each of the four between-person conditions.

Procedure

This research was approved and monitored by the Institutional Review Board of the University of North Carolina at Greensboro. People participated individually, and a researcher of the same gender conducted the experiment. After the participant provided informed consent, the experimenter explained that the purpose of the study was to assess physiological responses during mental effort, concentration, and attention. The participant expected to work on a computer task that required some effort, such as making quick decisions and judgments. The electrodes were then placed for the physiological assessments. After the signals stabilized, people completed a baseline period in which they completed demographic items and individual-differences surveys. The last 5 minutes of the baseline period were used for the baseline physiological values.

The parity task. After the baseline, participants completed a *parity task*, a popular mental-effort task in modern work (e.g., Chatelain & Gendolla, 2015; Silvia, Nusbaum, Eddington, Beaty, & Kwapil, 2014). Each trial of this task involved seeing a word in the center of the screen. The word is flanked by two numbers, and participants must judge whether the numbers have the same parity (both are odd or both are even) or different parity (one is odd and the other is even). Responses were collected using a high-speed keyboard with a timing accuracy of 1 ms. Each trial began with a fixation cross, shown for 350 ms, followed by the parity item (e.g., 4 HOME 6). The item stayed on the screen until the person responded, meaning that the difficulty of this task is unfixed—the participants were able to work at their own pace (Wright, Killebrew, & Pimpalapure, 2002). After the response, there was a 750 ms inter-trial interval before the next item appeared. All items were presented in black using 28-point Tahoma font on a white background. The task was controlled using MediaLab and DirectRT research software; the files are available at OSF (https://osf.io/3kwmr/).

Incentive manipulation. Incentive value was manipulated within person. Each participant worked on two blocks of the parity task, both three minutes long. The experimenter explained that people would receive a small amount of money, paid in cash at the end of the experiment, for each correct response. For one block, participants were told they would receive one cent per each correct response; for the other block, they would receive five cents. The people were informed that the goal was to get as many correct responses as possible, resulting in higher monetary reward.

The order of the incentives was counterbalanced between-subjects. Half the participants worked on the one-cent block first followed by the five-cent block; the other half worked on the five-cent block followed by the one-cent block. To minimize practice effects, two different item sets were used. Each set used different numbers (2, 3, 5, 8 vs. 4, 6, 7, 9) and different neutral words. The order of the item sets was counterbalanced between subjects.

Physiological Assessment

PEP and RZ were assessed using impedance cardiography. A Mindware Bionex chassis was used to collect the signals, which were sampled at 1000 Hz. The signals were filtered offline (.5-45 Hz for both EKG and dZ/dt, a low cutoff of 10 Hz for Zo, and a 60 Hz notch filter). Using spot electrodes, we used a modified Lead-II configuration to obtain an electrocardiogram (ECG), and a standard tetrapolar configuration to attain the impedance cardiogram (ICG). The ECG electrodes were placed on the right clavicle and on both sides of the participant's body at the lowest rib. The receiving pair of ICG electrodes was placed on the xiphoid process and the left clavicle. The sending pair of ICG electrodes was placed on the back (one 4 cm below the horizontal plane of the xiphoid process, and the other one 4 cm above the left clavicle).

The impedance data were scored using IMP 3.1 (Mindware, Gahanna, OH). Ensemble averages (Kelsey et al., 1998) were formed for each 60-second period, yielding 11 periods (5 baseline, 3 1-cent task, 3 5-cent task). The first physiological outcome was the RZ interval: the difference in ms between the R point on the ECG wave and the Z point on the dZ/dt wave. The second physiological outcome was the pre-ejection period (PEP): the difference in ms between the Q point on the EKG wave and the R point on the dZ/dt wave. The Q point was identified as the lowest point within 35 ms window before the R point of the ECG (Berntson et al., 2004). The B point was calculated using the Lozano et al. (2007) formula (RB = 55% of the RZ interval plus 4 ms). Figure 1 illustrates a representative ensemble average.

Results and Discussion

We conducted repeated-measures ANOVAs to evaluate the effects of time period (baseline, 1 cent, 5 cents) on PEP and RZ. There were no significant main effects or interactions involving the order and counterbalancing factors, so they were omitted from the final models. Polynomial contrasts were conducted to separate linear and quadratic effects. Table 1 shows the descriptive statistics. Note that higher sympathetic activity appears as smaller values of PEP and RZ—as the heart contracts more forcefully, the time interval captured by PEP and RZ is shorter.

We first explored the simple correlations between PEP and RZ. In all three periods, the two outcomes correlated very strongly: $r = .92$ (baseline period), $r = .94$ (1 cent incentive), and $r = .94$ (5 cent incentive).

Next, we examined if PEP or RZ had larger effect sizes for the manipulation of incentive value. For RZ, there was a significant within-person main effect, $F(2, 96) = 14.23$, $p < .001$, partial $\eta^2 = .229$. This was primarily due to a large linear effect, $F(1, 48) = 18.85$, $p < .001$, partial $\eta^2 = .282$. The quadratic effect was not significant, $F(1, 48) = 2.51$, $p = .119$, partial $\eta^2 = .05$. This pattern reflects, as expected, a decline in RZ from baseline as the incentive value increases, consistent with increased beta-adrenergic sympathetic activity during the blocks of the parity task.

For PEP, there was a significant within-person main effect, $F(2, 96) = 10.03$, $p < .001$, partial $\eta^2 = .173$. This overall effect was largely due to a significant linear effect, $F(1, 48) = 13.53$ $p < .001$, partial $\eta^2 = .220$. The quadratic effect was not significant, $F(1, 48) = 1.89$, $p = .175$, partial $\eta^2 = .038$ (see Table 1). Like RZ, increases in incentives caused smaller PEP values, consistent with past research on PEP and reward (e.g., Richter & Gendolla, 2009).

In summary, both PEP and RZ showed the expected change as a function of incentive value. The effect size for RZ, however, was slightly larger than the effect size for PEP, suggesting that it performed at least as well in capturing effort-related changes in contractility.

Study 2

In Study 2, we sought to replicate the effects from Study 1. In addition to recruiting a larger sample, we used a simpler design (only one level of incentive value) as well as a different incentive (3 cents per correct response).

Method

Participants and Design

A final sample of 89 women (age $M = 18.53$ years, $SD = 1.08$, range from 18 to 23) took part and received credit toward a voluntary research option in a psychology class. Approximately 45% of the sample identified as European American, 43% as African American, 8% as Hispanic or Latino, and 7% as Asian American (people could select more than one category).

Procedure

The data were from a larger study of perfectionism and effort (Harper et al., 2016). The procedure and physiological methods were essentially identical to Study 1, with one major modification. The participants completed only one 3-minute block for the parity task, and they were told they would receive 3 cents for each correct response, paid in cash, once the session ended. As before, RZ was estimated as the distance in ms between R and Z, and PEP was estimated using the Lozano et al. (2007) B-point method. PEP and RZ were computed for the baseline period (5 minutes) and task period (3 minutes).

Results and Discussion

As in Study 1, PEP and RZ correlated very highly in both the baseline (r = .92) and task (r = .94) periods. Repeated-measures ANOVAs examined change in RZ and PEP from baseline to task. Table 2 displays the descriptive statistics. Both RZ (F(1, 88) = 4.57, p = .035, partial η^2 = .049) and PEP (F(1, 88) = 2.95, p = .089, partial η^2 = .032) declined significantly from baseline to task, reflecting increased sympathetic influence during the task. Notably, as in Study 1, RZ had a larger effect size than PEP (partial η^2 = .049 vs .032).

Study 3

In Study 3, we sought to further replicate the effects from Studies 1 and 2. The procedure was essentially the same as in Study 2.

Method

Participants and Design

A sample of 71 women (age M = 19.13 years, SD = 1.32, range from 18 to 25) took part and received credit toward a voluntary research option in a psychology class. Approximately 48% of the sample identified as African American, 44% as European American, 13% as Asian American, and 8% as Hispanic or Latino (people could select more than one category).

Procedure

The procedure and physiological assessment were essentially identical to Study 2. After a 5-minute baseline period, people completed a 3-minute block of the parity task and were told they would receive 3 cents for each correct response. The physiological assessment and scoring were the same.

Results and Discussion

As before, PEP and RZ correlated highly in both the baseline (r = .89) and task (r = .92) periods. Repeated-measures ANOVAs examined change in RZ and PEP from baseline to task. Table 2 displays the descriptive statistics. Both RZ (F(1, 70) = 15.40, p < .001, partial η^2 = .180) and PEP (F(1, 70) = 10.52, p = .002, partial η^2 = .131) declined significantly from baseline to task. Notably, as in Studies 1 and 2, RZ had a larger effect size than PEP (partial η^2 = .180 vs .131).

Synthesis of Studies 1–3

All three studies found larger effects for RZ than for PEP. To estimate an overall summary, we conducted a quantitative synthesis of the effect sizes from the three experiments. The effect sizes were based on the change in PEP and RZ from baseline to task, using paired-sample *t*-values as the input statistic; for Study 1, the effect from baseline to the 5 cents condition was used. The analysis was conducted with the Comprehensive Meta-Analysis 2.2 software using a fixed-effects model and inverse-variance weighting. Table 3 reports the effect sizes (in Hedges's *g* metric) for each study along with the overall summary effect size synthesized across the 3 studies. Conventional guidelines view *g* values of .2, .5, and .8 as small, medium, and large effect sizes, respectively (Cumming, 2012).

For PEP, the overall effect size was g = .323 [95% CI: .185, .461], Z = 4.59, p < .001. For RZ, the overall effect size was g = .387 [95% CI: .248, .527], Z = 5.44, p < .001. RZ's effect size was thus roughly 20% larger than PEP's effect size. These summary effect sizes are good guides for researchers planning future research, and they suggest that RZ had an appreciable effect-size advantage over PEP in the present set of experiments.

Discussion

Research on mental effort emphasizes measures of sympathetic activity on the heart (Gendolla et al., 2012; Richter, 2012, 2013), and systolic blood pressure (SBP) and the pre-ejection period (PEP) have historically been the most popular ones. The present research explored the value of the RZ interval, also known as the initial systolic time interval (ISTI; Meijer et al., 2008), for assessing effort-related sympathetic activity. Like PEP, RZ reflects changes in sympathetically-mediated contractility. Unlike PEP, however, it is defined by two easily identified points.

The three experiments used a standard incentive paradigm to examine changes in PEP and RZ. As expected, all three studies found significant declines in PEP due to task incentives and thus replicate the large effort literature using PEP (Richter, 2012). RZ showed essentially similar patterns—like PEP, it declined significantly from baseline to task, reflecting greater contractility during the incentive task. Notably, the effect sizes were somewhat higher for RZ than for PEP in all three studies. When pooled quantitatively, RZ's weighted average effect size was around 20% larger than PEP's. This is consistent with the higher reliability associated with identifying the R and Z points. As noted earlier, impedance cardiography has a long history of developing methods for identifying and approximating Q and B (Árbol et al., 2017; Berntson et al., 2004; Lozano et al., 2007; Sherwood et al., 1990), which can be subtle waveform points that are not always apparent. Any errors associated with measuring these points feed into subsequent difference scores involving them.

The present research suggests that RZ is a promising metric for future research on the psychophysiology of mental effort in response to incentives. Obviously, much more research is needed to evaluate it across a wider range of contexts. But the present findings, taken together with past work, suggest that RZ deserves attention in future work. It's worth noting that two prior studies from our lab that did not use cash incentives found similar effects. One study found larger effects for RZ during an open-ended creative thinking task (Silvia, Beaty, Nusbaum, Eddington, & Kwapil, 2014), and another found a larger effect for RZ when people were asked to "do their best" on a parity task (Silvia, Nusbaum et al., 2014). Neither study offered explicit incentives, but they provide additional indirect support for exploring RZ further in mental effort research.

It is important to note that the conclusions regarding the relative effect sizes of RZ and PEP apply only for the PEP scoring method that was applied (Lozano et al., 2007). As noted earlier, many approaches to identifying and approximating PEP's points have been developed (Árbol et al., 2017; Forouzanfar et al., in press). These methods serve as more efficient alternatives to the laborious hand-scoring of individual cardiac cycles, but as in all psychological measurement, there can be trade-offs between cost (in time, training, and personnel) and precision. Comparing RZ to a range of alternate scoring methods, from other point-identification methods to hand-scored signals, is an important direction for future research. Likewise, the present experiments are limited to a particular paradigm: seated, still adults working on a mental effort task for cash rewards. It would be valuable to compare PEP and RZ in other contexts where sympathetic cardiac activity is commonly assessed, such as paradigms using mental stress, physical exercise, and pharmacological blockades. We strongly encourage researchers using other PEP scoring methods and other paradigms to explore RZ in their own data, which probably already contain the information needed to compute RZ.

In summary, RZ seems like a promising metric of effort-related sympathetic activity, particularly for research with large samples in which automated scoring methods save time and resources devoted to signal scoring. Likewise, RZ could prove fruitful for ambulatory impedance cardiography, given the noisier signals and wider range of postures and activities involved in ambulatory studies (Cybulski, 2011; Sperry et al., 2018).

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Table 1

Descriptive Statistics: Study 1

	Baseline	1 cent	5 cents
PEP	127.31 (1.36)	125.33 (1.46)	124.49 (1.50)
RZ	165.96 (2.47)	161.89 (2.58)	160.06 (2.69)

Note. *n* = 51 total participants. Because of missing data, some analyses are based on *n* = 50.

Standard errors are in parentheses. PEP = pre-ejection period (in ms); RZ = RZ interval (in ms).

Table 2

Descriptive Statistics: Studies 2 and 3

	Study 2		Study 3	
	Baseline	3 cents	Baseline	3 cents
PEP	119.96 (1.13)	119.14 (1.17)	130.37 (.97)	128.80 (1.08)
RZ	159.24 (1.74)	157.45 (1.81)	173.11 (1.66)	169.83 (1.92)

Note. Study 2 n = 89; Study 3 n = 71. Standard errors are in parentheses. PEP = pre-ejection period (in ms); RZ = RZ interval (in ms).

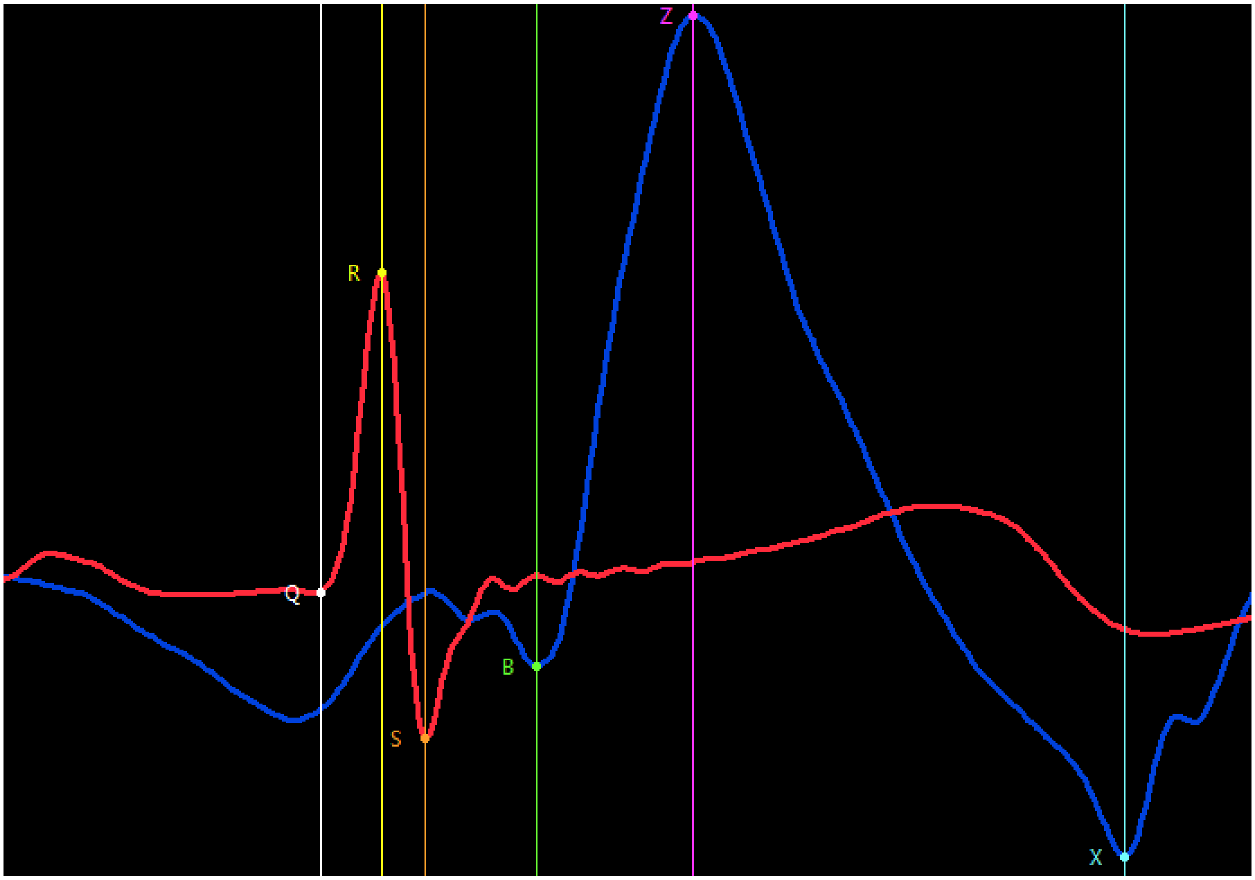
Table 3

Synthesis of Effect Sizes: Studies 1–3

	PEP	RZ
Study 1	.516 [.225, .807]	.608 [.310, .905]
Study 2	.181 [-.027, .388]	.225 [.016, .433]
Study 3	.381 [.142, .619]	.461 [.218, .703]
Summary Effect	.323 [.185, .461]	.387 [.248, .527]

Note. Effect sizes are Hedges's *g* coefficients; 95% confidence intervals around *g* are in brackets. The summary effects and confidence intervals are from a fixed-effects meta-analysis. The input data are available at https://osf.io/3kwmr/.

Figure 1. **An illustration of PEP and RZ.**



Note. PEP is the time between the Q and B points. RZ is the time between the R and Z points. Note that R and Z are salient points defined by the peaks of major waveforms. The figure comes from a 60-second ensemble average, and the points were identified by the Mindware IMP 3.1 software according to the description in Study 1.