Supplemental Digital Content 1: Standard vs. Variable Treatment Groups

A between-subjects factor of treatment variability (constant vs. variable treatment) was included in the full design of the present experiment. However, as no substantive difference between the two groups was observed across most outcome variables tested, results are presented as supplemental digital content.

There were two primary reasons for adding this manipulation. First, adding variability to treatment outcomes increases the ecological validity of the task; for example, headache pain is not always consistent and background fluctuations in symptomology can make treatments appear more or less effective. Second, given the paucity of research in this area, we were not sure how difficult it would be for participants to learn to discriminate between the different levels of shock associated with the three options (optimal, suboptimal and no treatment). To avoid the learning task being too hard (if nothing is learned during conditioning, then the placebo effect cannot occur), or easy (if learning happens too fast, then all subjects will choose the option associated with less pain, in which case the choices become uninteresting to study), the two groups were included with the rationale that learning should be more difficult for those in the variable group. By altering learning difficulty in this manner, we hoped to have a better chance of being able to study the explore-exploit tradeoff.

Design

A between-subjects manipulation of outcome variability was employed during the conditioning phase of the experiment, but not at test. In the constant condition, the optimal and suboptimal treatments always produced 50% and 60% of the shock compared to the no treatment condition, which was delivered at 100% of the participants pain tolerance. In the

variable condition, the shocks associated with the optimal and suboptimal treatment had the same mean shocks of 50% and 60% but varied with a standard deviation of 10.5% on a trial-by-trial basis. In both groups the no treatment option always produced 100% shock with zero variance. The design of the full experiment is outlined in Table 1. The shocks on treatment trials for the variable group were preprogramed to conform closely to a normal distribution; there were 8 shock intensities uniformly distributed from .05 to .95 percentiles. For the variable group, shocks delivered in each block were randomly sampled from the distributions in Table 2, without replacement. Distributions reset when a given list was exhausted.

Table 1: Summary of experimental design (*Nb.* means and standard deviations refer to the percentage of the participants total pain tolerance at which shocks were delivered).

Group	Conditioning *(3 Blocks of 10 trials)*	Test *(3 blocks of 10 trials)*
Constant *(TENS treatments appear consistent)*	2 No TENS (M = 100, SD = 0) 8 TENS Choice Optimal (M = 50, SD = 0) Suboptimal (M = 60, SD = 0)	1 No TENS (M = 100, SD = 0) 1 Optimal (M = 100, SD = 0) 1 Suboptimal (M = 100, SD = 0)
Variable *(TENS treatments model background fluctuation in symptoms)*	2 No TENS (M = 100, SD = 0) 8 TENS Choice Optimal (M = 50, SD = 10.5) Suboptimal (M = 60, SD = 10.5)	1 No TENS (M = 100, SD = 0) 1 Optimal (M = 100, SD = 0) 1 Suboptimal (M = 100, SD = 0)

Table 2: Distribution of shocks in the variable treatment efficacy condition. (*Nb.* numbers represent the percentage of the participant's pain tolerance level at which shocks were delivered, as well as the percentile from which they were selected).

Percentile (SD = 10.5)	0.05	0.178	0.307	0.435	0.564	0.692	0.821	0.95
Optimal Treatment (% tolerance)	43.551	50.792	54.960	58.381	61.618	65.039	69.208	76.448
Suboptimal Treatment (% tolerance)	33.551	40.792	44.960	48.381	51.618	55.039	59.208	66.448

Results

Conditioning and test phase univariate analyses are presented below. The ANOVAs reported are identical to those presented in the manuscript with the exception that the between-subjects factor of group (Treatment Variability: Constant vs. Variable) is included in the model. Overall statistical significance associated with the factors included in both models is consistent. However, due to the inclusion of the additional between-subjects factor, reported values vary slightly between models.

Demographic Information

There were no differences in age, $t(60) = .34$, $p = .735$, Cohen's $d = .09$, 95% CI[-1.33, 0.95], or gender χ^2 (1) = 0.07, $p = .80$, Cramer's $V = .03$, between the constant (n = 31, 52% female, mean age = 19.3 years, ± 2.1 *SD*) and variable (n = 31, 55% female, mean age = 19.5 years, ± 2.3 *SD*) groups.

The Conditioning Phase: Univariate Analyses

Table 1: Univariate analyses during the conditioning phase of the experiment with treatment variability included in the model.

Outcome	Effects / Contrasts	Predictor	*F*	*p*	η_p^2
Pain Ratings	Between Subjects	Group *(standard vs. variable)*	0.49	.486	.01
	Contrast 1: Overall Placebo (treatment vs. no treatment)	Treatment	373.10	<.001	.86
		Treatment * Group	1.27	.264	.02
	Contrast 2: Differential Placebo (optimal vs. suboptimal)	Treatment	149.11	<.001	.71
		Treatment * Group	**6.49**	**.013**	**.10**
Expectancy Ratings	Between Subjects	Group *(standard vs. variable)*	0.03	.854	<.01
	Contrast 1: Overall Placebo (treatment vs. no treatment)	Treatment	114.21	<.001	.66
		Treatment * Group	2.51	.118	.04
	Contrast 2: Differential Placebo (optimal vs. suboptimal)	Treatment	33.84	<.001	.36
		Treatment * Group	1.09	.301	.02
Electrodermal Response	Between Subjects	Group *(standard vs. variable)*	<0.01	.982	<.01
	Contrast 1: Overall Placebo (treatment vs. no treatment)	Treatment	16.52	<.001	.23
		Treatment * Group	2.84	.098	.05
	Contrast 2: Differential Placebo (optimal vs. suboptimal)	Treatment	4.57	.037	.07
		Treatment * Group	0.02	.888	<.01
Choice: Optimal Choice	Between Subjects	Group *(standard vs. variable)*	0.65	.424	.01
	Within Subjects	Trial *(blocks 1 – 3)*	5.47	.005	.08
	Interaction	Trial*Group	0.21	.812	<.01
Choice: Switch Rate	Between Subjects	Group *(standard vs. variable)*	1.44	.235	.02
	Within Subjects	Trial *(blocks 1 – 3)*	17.96	<.001	.23
	Interaction	Trial*Group	0.63	.535	.01

Conditioning Phase: Summary

No main effects or interaction terms involving treatment variability (Constant vs. Variable) were observed across the conditioning phase, with the exception of an interaction of treatment type (differential placebo effect: optimal vs. suboptimal treatment) and group when pain ratings were the outcome variable. However, simple effects comparing the treatments did not reach statistical significance (all *ps*>.41), suggesting that any difference was minimal. For descriptive statistics see Figure 1.

The Test Phase: Univariate Analyses

Table 2: Univariate analyses during the test phase of the experiment with treatment variability included in the model.

Outcome	Effects / Contrasts	Predictor	*F*	*p*	η_p^2
Pain Ratings	Between Subjects	Group *(standard vs. variable)*	0.03	.869	<.01
	Linear Trend	Trial	0.09	.761	<.01
		Trial*Group	0.39	.535	.01
	Contrast 1: Overall Placebo (treatment vs. no treatment)	Treatment	62.42	<.001	.51
		Treatment * Group	**4.73**	**.034**	**.07**
		Trial * Treatment	24.99	<.001	.29
		Trial * Treatment * Group	0.05	.818	<.01
	Contrast 2: Differential Placebo (optimal vs. suboptimal)	Treatment	20.80	<.001	.26
		Treatment * Group	1.85	.178	.03
		Trial * Treatment	0.61	.438	.01
		Trial * Treatment * Group	2.80	.100	.05
Expectancy Ratings	Between Subjects	Group *(standard vs. variable)*	0.03	.864	<.01
	Linear Trend	Trial	10.42	.002	.15
		Trial*Group	0.35	.555	.01
	Contrast 1: Overall Placebo (treatment vs. no treatment)	Treatment	89.29	<.001	.60
		Treatment * Group	0.59	.444	.01
		Trial * Treatment	10.06	.002	.14
		Trial * Treatment * Group	1.90	.174	.03
	Contrast 2: Differential Placebo (optimal vs. suboptimal)	Treatment	19.96	<.001	.25
		Treatment * Group	3.37	.071	.05
		Trial * Treatment	1.90	.174	.03
		Trial * Treatment * Group	0.25	.620	<.01
Electrodermal Response	Between Subjects	Group *(standard vs. variable)*	0.38	.541	.01
	Linear Trend	Trial	3.94	.052	.07
		Trial*Group	0.55	.462	.01
	Contrast 1: Overall Placebo (treatment vs. no treatment)	Treatment	45.49	<.001	.44
		Treatment * Group	0.63	.432	.02
		Trial * Treatment	0.30	.584	.01
		Trial * Treatment * Group	1.10	.299	.02
	Contrast 2: Differential Placebo (optimal vs. suboptimal)	Treatment	1.00	.320	.02
		Treatment * Group	1.01	.318	.02
		Trial * Treatment	0.74	.392	.01
		Trial * Treatment * Group	0.07	.787	<.01

Test Phase: Summary

Limited difference between the constant and variable group was observed at test. An interaction between group and treatment type was observed. However, unlike the conditioning phase, this was isolated to the overall placebo effect, whereby participants in the constant group demonstrated a greater placebo effect for both treatments relative to no treatment (*M Difference* = 11.78, 95% CI [15.53, 7.98]) compared with the variable group (*M Difference* = 6.68, 95% CI [9.60, 3.77]). Descriptive statistics are presented in Figure 1.

Discussion

Treatment variability was manipulated in order to simulate fluctuations in treatment efficacy that are likely to occur with successive treatment administration. Variability was therefore expected to inhibit discrimination between treatments, reducing both the tendency to exploit the optimal treatment and limiting the placebo effect at test. However, treatment variability did not alter optimal choice or switch rate between treatments. Differences in pain ratings were observed between the constant and variable group, both during conditioning and at test. However, these results were inconsistent, being isolated to the differential placebo effect in the case of the former and the overall placebo effect in the latter. Further, group differences did not translate to measures of expectancy or autonomic arousal.

It is possible that modelling greater variability in shock intensity may have made any group differences more apparent. While treatment variability was included as proof of concept in the present study, future research may wish to manipulate variability to differing degrees in order to determine the extent to which fluctuations in pain outcomes alter both treatment choice and the placebo effect.

Table 2: Univariate analyses during the test phase of the experiment with treatment variability included in the model.

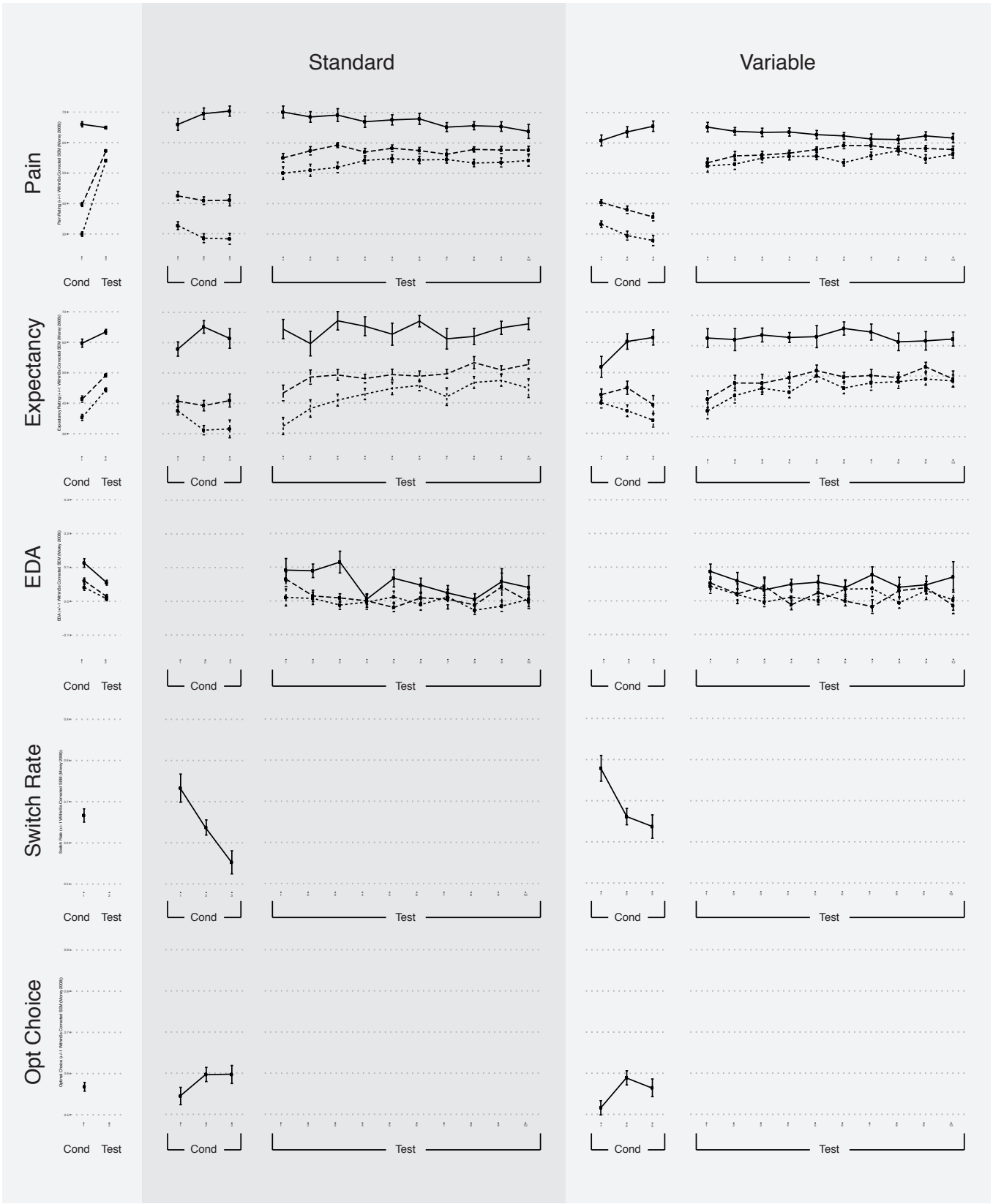

Figure 1: data included in univariate analyses of the conditioning and test phase, split by treatment variability.