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Digital signatures: a tool to prevent and predict dishonesty?

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Abstract

Dishonesty is prevalent and causes great damage to society. On an individual level, besides reaping rewards, it also carries a psychological cost for those who engage in it. This principle is used to make people more honest with behavioral interventions, one of them being the well-known 'signature nudge'. Digital transition in society has however led to changes in the way people sign, which may affect the effectiveness of this nudge. In two experiments, the current study investigates the relationship between digital signatures and honesty, building on previous research by examining novel signature types, the moderating role of personal characteristics, effect decay, and the predicting value of digital signature characteristics. Results show no effect of any signature intervention and no unilateral relation between digital signature characteristics and subsequent behavior. These findings contrast with earlier research and cast doubt on the use of signature interventions as a tool to prevent or predict dishonest behavior.

Keywords Dishonesty · Morality · Nudging · Signature

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1 Introduction

Individuals continuously encounter opportunities in which dishonest behavior can result in personal gain (Jacobsen et al. 2018). While most acts of cheating may be of small size, they appear to be quite common (Ariely 2012). As such, dishonesty leads to substantial damage to society, both economically and socially (Houser et al. 2016). In recent years fraud statistics have shown a worrying increase with new reached heights (CBS 2017; Financial Fraud Action 2017; Finklea 2014; Javelin 2017), of which a crucial part may be due to the dishonest reporting of information.

Arrow (1972) put forward that virtually every commercial transaction has within itself an element of trust. This comes with opportunities for abuse of which tax authorities and insurance companies are well-known victims. These organizations collect declarations and claims, but, sadly, not all people who submit information do this honestly. Careful investigation of all data is not feasible and will not always lead to the detection of fraudulent information. This calls for a preventive approach, in which 'nudging' can help.

"To nudge" is, in the most literal sense, "to push slightly or gently in a desired direction" (Nudge, n.d.). In behavioral sciences, nudging is known as the act of altering choice architecture, which is the design in which choices are presented (Thaler and Sunstein 2008). In automatic rather than deliberate ways, the environment in which people act has important effects on their behavior (Dolan et al. 2012). According to Thaler and Sunstein (2008), a neutral environment does not exist and any design decision will influence behavior. As such, subtle alterations in products and services may either promote or curb criminal behavior (Clarke and Newman 2005).

Various experimental studies have shown that nudge interventions can be employed to decrease dishonesty (e.g., Mazar et al. 2008; Shu et al. 2011; McDonald et al. 2017; Leal et al. 2016), but one specific intervention in particular has received a major amount of attention. In the study of Shu et al. (2012), cited in 289 works (according to Google Scholar, on July 1, 2019), it was shown that a signature at the beginning of a form can majorly benefit honesty. Problematically, however, this study focused on signatures in their traditional form, drawn physically, often with pen(cil) and paper. In current, increasingly digital, times, paper forms are a rare sight. Organizations and governments are pushing for online, electronic communication (Finger and Pécoud 2003; Meijer 2015), which changes the nature of signatures.

In a study titled "Paperless and soulless [...]", Chou (2015a) put forward the impact of this change. Digital signatures, or 'e-signatures', are not perceived as symbolically equivalent to pen-and-paper signatures. Experiments showed that digital signatures may evoke a weaker sense of the signer's presence and involvement, and that, accordingly, people perceive the value of electronically signed documents to be lower: job applications are more likely to be discounted and the chance of contract breach is evaluated as higher. This poses a problem for the digitalization of data collection, which comes with a way of signing, that is, as Chou (2015a) states, already prevalent.

The current study aims to further explore the relationship between digital signatures and honesty. It investigates the effects of novel digital signatures, and tests whether various mechanisms that were found in previous studies apply to digital signatures. The accompanying research question is as follows:

RQ “What is the relationship of digital signatures to individual honesty?”

2 Background and Hypotheses

Signatures are used to confirm identity and to declare intent in various areas of life (Barner 1999). Not until signed, an agreement becomes binding, a declaration can be submitted, or a diploma is awarded. One’s signature carries legal power, but, as demonstrated by Shu et al. (2012) and Chou (2015b), may also serve as a psychological tool which promotes honesty.

Following classical crime theory (Becker and Landes 1968), dishonesty takes place when it offers greater expected utility than honesty. Individuals are thought to consider the expected cost of punishment and the benefits of the dishonest act, and make a rational economic decision. Classical rational economics, however, have fallen out of grace (Ariely 2009). A classical economic perspective on honesty does not explain why tax compliance is as high as it is, when the chance and severity of fines are low (Feld and Frey 2007). It does not explain why people limit their use of lies, when lies cannot be detected (Shalvi et al. 2011). And, it does not explain why moving a signature field to the start of a form promotes honesty (Shu et al. 2012), when it does not impact the expected utility of fraud.

Current theories on honesty apply a more sophisticated approach, in which the moral state management of an individual plays a central role. Mazar et al. (2008) present the Theory of Self-Concept Maintenance which consists of the notion that people like to consider themselves as good and honest, but are also attracted to the benefits of dishonesty. Therefore, individuals will perform dishonest behavior, but only to the extent under which they can maintain their positive view of self. Put differently, dishonest behavior reaps the individual benefits, of economic or other nature, but also causes the individual harm in the form of a psychological cost (see also Thielmann and Hilbig 2019). Strongly related to this idea is the Moral Balance Model by Nisan (1991), under which an individual’s moral balance score is computed from their former behavior, good or bad. When deciding upon moral behavior, people will evaluate what impact an action will have on their score and aim to keep it above their personal standard.

To reduce or entirely avoid the psychological cost of dishonesty, individuals can first and foremost alter their behavior (i.e., not engaging in dishonest behavior or only to a limited extent). They can also, however, apply tactics that make it easier to cope with their dishonest behavior. Bandura (1986) coined eight interrelated ‘moral disengagement’ mechanisms, which explain how moral self-regulation may be bypassed. In short, people cognitively misconstrue unethical behavior to increase its moral acceptability, distort the effects of harmful actions, and reduce identification with victims. Relatedly, Shalvi, Gino, Barkan, and Ayal (2015) find that people apply self-serving justifications when they engage in ethical violations. Shu et al. (2011) show that people exhibit moral disengagement and appear to forget moral information when lying. These processes demonstrate how individuals can participate in dishonest behavior while avoiding negative self-signals.

Such tactics may, however, be countered by choice architectural cues. In the REVISE framework, Ayal, Gino, Barkan, and Ariely (2015) put forward thee principles to defeat dishonesty: reminding (boosting people's moral salience with subtle cues), visibility (increasing people's feeling that they are being seen and identified), and self-engagement (bridging the disparity between people's abstract moral image and actual behavior). For instance, honor codes, relying on the reminding principle, have successfully promoted honesty by making people attentive to their own moral standards, which results in dishonest actions having a higher impact on one's self-concept (Mazar et al. 2008; Shu et al. 2011). As another example, covered under the visibility principle, in the presence of mirrors people act more honestly (Vincent et al. 2013; Gino and Mogilner 2014).

Ayal et al. (2015) classify the signature intervention applied by Shu et al. (2012) under the self-engagement principle as it obtains self-commitment to act morally prior to behavior. Chou (2015b) extensively sets out an explanation on the honesty promoting effect of signatures, arguing that signatures prompt commitment and compliance because they are powerful symbolic representations of the self. In this line, the symbolic value of a signature may serve as a moral cue (which boosts moral salience), whereas the connection to the self may induce self-awareness. As such, a signature may tap into all three of the principles of the REVISE framework, which would contribute to its effectiveness in curbing dishonesty.

In the following sections unanswered questions about promoting honesty through signature interventions are defined. The aim of the research is to conceptually replicate the signature honesty effect and to then deepen our understanding of it. Summarily, this research will examine the honesty effect of various digital signature interventions, how individual differences may moderate this effect, how this effect sustains with repeated choices and over time, and if digital signature characteristics can predict dishonest behavior.

2.1 Signature type

While pen-and-paper signatures may be very effective at promoting honesty (Shu et al. 2012), digital signatures seem unable to achieve the same. In multiple experiments, Chou (2015b) shows that digital signatures do not increase honesty. There is, however, one exception: a drawn digital signature, which individuals set through drawing their signature with a computer mouse. Unlike clicking a checkbox, entering a PIN, or typing one's name, this type of signature managed to evoke self-presence in participants and to curb dishonesty.

As Chou (2015b) notes, individuals react differently to information written by hand compared to information submitted electronically. James and Engelhardt (2012) have shown that writing a text may lead to higher cognitive engagement than typing it. Furthermore, when people take notes by keyboard, compared to taking notes by hand, it leads to less information internalization and retention (Mueller and Oppenheimer 2014). Relatedly, experiments show that dishonesty is more prevalent in e-mail communication than it is in pen-and-paper communication (Naquin et al. 2010).

To assess whether a mouse drawn signature is equal to a pen-and-paper signature, Chou (2015b) performed an experiment in which participants could misreport their performance on an anagram solving task. The results showed no significant differences and, therefore, Chou (2015b) concluded that the signature transmission method should not matter. However, given the experiment's small sample size (N = 50), and therefore low statistical power,[1] this cannot be taken for granted.

The current state of technology allows for novel signing options, such as a touch drawn signature or uploading a photo of a pen-and-paper signature. Even for the most experienced users it can be hard to make an accurate representation of their signature using a mouse. Drawing with a mouse may feel alien and never quite like regular drawing, while drawing using touchscreen may come as more natural and easy, with the user being in direct haptic contact with the device. Consequently, psychological differences similar to those between typing and writing may exist. This makes it worthwhile to investigate the honesty effects of novel drawn digital signatures, which leads to the following hypothesis:

H1 "Signature type moderates the honesty effect of digital signatures"

2.2 Individual characteristics

Individual differences may moderate the effect of honesty nudging and signature interventions.

2.2.1 Digital skills level

The 'digital divide', a term first coined in the second half of the 1990s, refers to the issue of inequality that has surged in the information age (Van Dijk 2006). Although it first referred to the problem of unequal access to the internet, the focus has shifted to the 'second-level digital divide', which concerns differences in people's online skills (Hargittai 2002; Van Deursen and Van Dijk 2011).

As Van Deursen and Van Dijk (2011) show, particularly lower educated individuals experience difficulties in the use of internet technology. For all skill types (operational, formal, informational, and strategic), educational level is a major predictor. Age is also an important factor, but is only a predictor of operational and formal skills. Chou (2015b) notes that digital signatures may evoke less self-presence

[1] A sensitivity power analysis (conducted with GPower 3.1 [Faul, Erdfelder, Lang, & Buchner, 2007], using a one-tailed alpha significance criterion of .05, a power criterion of 80, and, as in the study, a group 1 sample size of 28 and a group 2 sample size of 22) showed a required effect size of .72 (Cohen's *d*). Following Cohen (1988), this would be a near large effect.

because such technology is relatively new; only 34% of the U.S. workforce grew up with computers at home (File 2013) (p. 92).

Between generations and digital skills levels, there may be vast differences in how digital signatures are used and perceived, and therefore also in what psychological effect they may cause. This leads to the following hypotheses:

H2 "Digital skills level moderates the honesty effect of digital signatures"

H3 "Age moderates the honesty effect of digital signatures"

2.2.2 Financial well-being

Financial well-being, defined as the extent to which individuals have financial security and freedom of choice in the present and the future (CPFB 2015), may be an important factor in people's behavior. Budgeting, saving, risky credit card behaviors and compulsive buying are all significantly related to financial well-being (Gutter and Copur 2011). A field experiment performed by Bhanot (2017) aimed to increase loan repayment rate with honor pledges, but found minimal impact—with the author concluding that borrowers that fail to repay are often simply unable to do so because of financial hardship.

For those in worse financial situations, earning extra may take priority over maintaining a positive self-concept, or, given their troubles, dishonesty may be perceived as less immoral or justified. As such, those individuals may be less susceptible to honesty nudging interventions. At different levels of financial well-being the effect of a honesty nudge may differ. This leads to the following hypothesis:

H4 "Financial well-being moderates the honesty effect of digital signatures"

2.2.3 Narcissism

The American Psychiatric Association (2013) defines narcissistic personality disorder as a "pervasive pattern of grandiosity (in fantasy and behavior), need for admiration, and lack of empathy…" (p. 645). Grijalva et al. (2015) note that, besides this clinical conceptualization, a continuous personality attribute of narcissism exists which has been frequently studied and connected to a wide range of consequential outcomes. For example, narcissism has many links to unethical and fraudulent behavior (Lambe et al. 2018; Blickle et al. 2006; Williams et al. 2010).

Narcissists have a different, more positive, view of self, and appear to operate under a lower level of moral engagement. As such, they may react differently to a honesty nudge which relies on the connection between morality and the self-concept. This leads to the following hypothesis:

H5 "Narcissism moderates the honesty effect of digital signatures"

2.3 Effect decay

Shu et al. (2012) have established that a signature intervention only has an effect on honesty if it is placed before the information reporting moment. Howard, Roe, Nisbet, and Martin (2017) observe that the effect of a honesty priming intervention fades away when individuals are confronted with repeated choices. An analysis of the data of the study that Howard et al. (2017) performed an online replication of (viz., De-Magistris et al. 2013) reveals the same pattern. In two stages of a dictator game, d'Adda et al. (2017) also show the decay of the effect of push and nudge interventions on altruism.

This suggests that honesty nudges temporarily put people in a state during which their behavior is improved, and that, with repeated choices or over time, people will gradually return to their default state. For the design of reporting procedures this is an important phenomenon to examine, which leads to the following hypotheses:

H6 "The honesty effect of digital signatures decreases with repeated choices"

H7 "The honesty effect of digital signatures decreases over time"

2.4 Dishonesty prediction

Signature size has been established as a measure of confidence (Bogan and Jankovic 2018; Zweigenhaft 1977; Zweigenhaft and Marlowe 1973; Warner and Sugarman 1986) and dominance (Jorgenson 1977; Mailhos et al. 2016). Recently, research has also connected signature size to narcissism (Ham et al. 2018; Mailhos et al. 2016).

In an experimental setting, Ham et al. (2018) find that signature size, as a measure of narcissism, predicts misreporting. They validate this result through the examination of notarized signatures of chief financial officers (CFOs) and their organizations, finding that CFO signature size is associated with poor financial reporting quality (viz., more earnings management, less timely loss recognition, weaker internal control quality, and a higher probability of restatements).

It is worth investigating if this finding can be extended to digital signatures. If so, besides preventing dishonesty, digital signatures may be employed as a fraud indicator. This leads to the following hypothesis:

H8 "Digital signature characteristics predict dishonesty"

In two experiments, the relationship of digital signatures to honesty is examined and the hypotheses are tested. Experiment 2 was setup to address the limitations of first experiment and to extend upon it. Therefore, H4 and H5 were only part of the latter experiment.

3 Experiment 1

In cooperation with a Dutch governmental organization, the first experiment tested the effect of various digital signatures in a panel of agricultural entrepreneurs.

3.1 Method

3.1.1 Procedure

Participants were asked to fill in an online questionnaire for improvement of the online services of the organization. Similar to an honesty experiment by Chou (2015b), they were told that the organization was interested in how long it takes people to read four sample texts. Therefore, the organization needed participants to measure how long they spent reading each text. Participants were informed that with longer reading time, they would have more chance of winning one of the lottery prizes (50 vouchers, all worth 20 euros).[2] Unbeknownst to the participants, the survey software also measured the time that the participants spent reading, which allowed for the measuring of dishonest overreporting behavior.

After reading all of the texts, participants' digital skills level was measured [using a digital skills level scale developed by Van Deursen et al. (2014)]. Demographic variables (age, gender, and educational level) were supplied by the research agency that managed the customer panel. At the end of the survey, participants were asked to describe what they thought that goal of the survey was. Dependent on their condition, they were also asked an additional question about their device input method (see 3.1.2).

At the start of the survey, participants were told that their honesty would be relied upon in this research. Participants were randomly assigned to one of five experimental conditions. If assigned to a signature condition, they were asked to sign via a designated website to continue. After submitting their signature, they received a randomly generated code which they had to enter in the survey.

3.1.2 Experimental conditions

Table 1 presents the five experimental conditions.

The signature conditions were designed to be as identical to each other as possible, differing only where essential for the specific signing method. For the electronic drawing conditions, a website with a sophisticated electronic canvas was employed [making use of Nowak's (2018) HTML5 signature pad which is based on code by Dickerson (2012)]. Bézier curve interpolation allowed for smooth,

[2] Dissimilar to Chou (2015b), participants were not paid extra per 5 s reading time. The research agency that managed the customer panel was not able to individually pay participants, which is why a lottery was used to create incentive for cheating. This is, however, believed to not impact participant behavior (Starmer and Sugden 1991).

Table 1 Experimental conditions

Condition	Description
Control	Participant provides no signature
Mouse drawn signature	Participant draws signature with a computer mouse
Touch drawn signature	Participant draws signature with a touch device (touchscreen or touchpad)
Pen-and-paper drawn signature	Participant draws signature with a pen(cil) and paper, takes a photo of it, and uploads it
Checkbox signature	Participant provides signature by clicking a checkbox of an honesty statement ('I declare to answer honestly' in Dutch)

Fig. 1 Screenshots of the mouse/touch, pen-and-paper, and checkbox signature websites

pen-and-paper like drawing, with high responsiveness to a user's input. Figure 1 displays screenshots of the websites.

In order to guarantee a logical flow, participants that participated via mobile devices were not able to be assigned to the mouse drawn signature condition. As participants that take part using laptop and desktop computers may use varying input methods, those in the mouse drawn signature condition were asked about how th–ey control their computer (mouse, touchscreen, touchpad, or other). Four participants indicated that they used a touchpad and two participants indicated to have made use of a touchscreen; in the analysis, these participants were regarded as having participated in the touch drawn signature condition. For all signatures submitted by participants that were originally assigned to the touch drawn signature condition, the website performed a check to verify to confirm that human touch was indeed used to sign [making use of code by Gilbertson (2016)]. For thirteen participants, touch could not be detected; these participants were therefore regarded as having participated in the mouse drawn signature condition.

Submitted signature codes of the survey were matched with the generated codes in the database, in order to link survey data to signature data.[3] Seventeen participants were not willing to sign, and entered a fake code. One participant in the pen-and-paper drawn signature condition uploaded an unrelated photo. These participants were regarded as having participated in the control condition, as they did not provide a valid signature.

3.1.3 Sample

1514 agricultural entrepreneurs, all part of the organization's customer panel, were invited to participate.

675 participants started the survey, and 322 completed it. Of the 353 that did not complete the survey, 27 cancelled their participation on the first page (introduction and informed consent). 277 quit on the page where a signature was required to continue. Cancellation was particularly high among those originally assigned to the pen-and-paper drawn signature condition (N = 119) and the touch drawn signature condition (N = 80), while lower among those originally assigned to the mouse drawn signature condition (N = 43) and checkbox signature condition (N = 35). No participants originally assigned to the control group cancelled their participation on the condition page. 49 participants cancelled their participation at a later point in the survey.

Participants that did not complete the survey in full were excluded from the analysis. Three participants that correctly identified the goal of the study were also excluded, leading to a final sample of 319 participants (age mean = 53.32, age SD = 9.834, age min. = 28, age max. = 77, male % = 83.7, female % = 15, unknown gender % = 1.3), with 118 in the control condition, 65 in the mouse condition, 46 in the touch condition, 20 in the pen-and-paper condition, and 70 in the checkbox condition.

3.1.4 Analysis

To test H1, H2, and H3, a UNIANOVA model for overall overreporting rate (DV, continuous) was formed, with as predictors digital skills level (IV, continuous), reading time (IV, continuous), age (IV, continuous), gender (IV, categorical [male/female]), educational level (IV, categorical [low/high; those in possession of at least a bachelor's degree were considered as higher educated]), the experimental condition (IV, categorical), and interaction terms for the experimental condition and each other independent variable. H6 and H7 were tested by, respectively, a repeated measures ANOVA model using the same variables, and a UNIANOVA model using restructured data (in which each text's reporting moment represents a case with z-scores of overreporting rate per text) with time elapsed since signature

[3] Signature data for two participants was not saved due to a database upload error. In the case of such a problem, the signature websites were designed to provide the participant with a hardcoded, non-random, client-side code, so that they could continue their participation regardless (and under the assumption that their signature was successfully processed).

Table 2 Signature characteristics computed for mouse and touch drawn signatures

Signature characteristic	Description
Canvas size	Total number of pixels in the canvas
Pixel number (absolute)	Number of drawn pixels in the canvas
Pixel number (relative)	Number of drawn pixels, divided by total number of pixels in the full canvas
Trim size (absolute)	Number of pixels when the signature image is trimmed to the smallest rectangular form
Trim size (relative)	Number of pixels when the signature image is trimmed to the smallest rectangular form, divided by total number of pixels in the full canvas
Time spent signing	How many seconds a participant spent signing before signature submission
Times cleared	How many times a participant cleared the canvas

code submission (IV, continuous) added. H8 was tested in linear regression analyses predicting overall overreporting rate (DV, continuous), separately performed for each signature characteristic (IV, continuous, as listed in Table 2); mouse and touch drawn signatures were analyzed both individually and combined, as it was deemed possible that signature characteristics would show a different trend per transmission method, while a combination could increase statistical power.

Overall overreporting rate was computed by subtracting the total reading time recorded by the survey from the total reading time reported by participants, and calculating the proportion of this value compared to the total reading time recorded by the survey. Prior to this, formatting errors of participants (entering seconds as minutes and milliseconds as seconds in the *mm:ss* format) were corrected.

To deal with extreme overreporting and survey measured time, an extreme z-value test with multiple iterations was applied where applicable. In each iteration, the z-score was calculated for the given value list. If the highest absolute z-score was higher than five, the corresponding value was marked as extreme and not used it the next iteration. This was done until an iteration yielded no extreme values. All extreme values were then recoded to the mean plus (or minus) five standard deviations of the final iteration.

3.2 Results

On average participants overreport their overall reading time by 25.41% (SD = 46.41%). Figure 2 shows the mean overall overreporting rate per experimental condition.

As displayed in Table 3, UNIANOVA analysis shows no mean inequality of overreporting rate between the experimental conditions. As such, the interventions do not have an impact on honesty, and all interventions appear to affect honesty equally (H1). Overall reading time is significantly positively associated with overall overreporting rate. As can be seen in Fig. 3, this holds true for all conditions but the pen-and-paper condition, which is reflected in the significant interaction effect between experimental condition and reading time. Furthermore, a higher educational level is near significantly associated with less overreporting. From the lack of interaction between digital skills level and age with experimental condition, it can be concluded that no evidence is found for a moderating role of these factors (H2, H3).

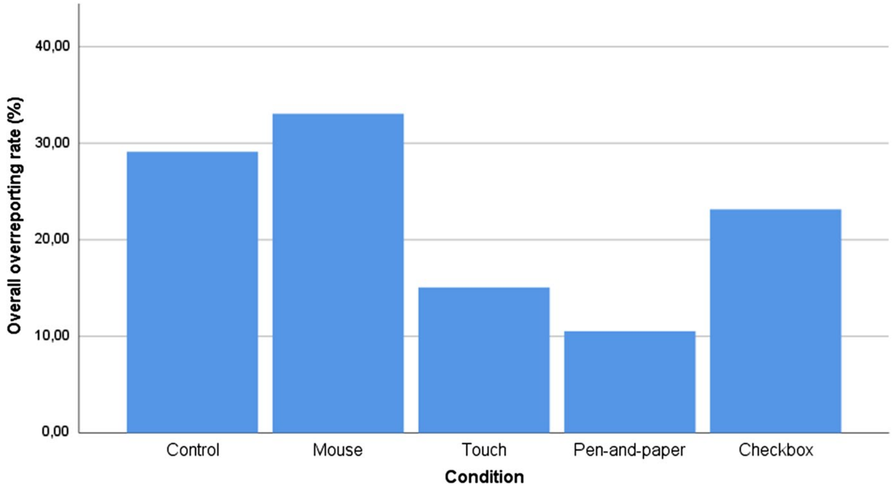

Fig. 2 Mean overall overreporting rate per experimental condition

Table 3 UNIANOVA of participant characteristics and experimental condition (IVs) on overall overreporting rate (DV)

IV	Individual			In interaction with experimental condition		
	F	*p*	η^2	F	*p*	η^2
Digital skills level	= .249	= .618	= .001	= 1.592	= .177	= .022
Reading time	= 14.134	< .001***	= .048	= 4.987	= .001***	= .067
Age	= .024	= .877	< .001	= .437	= .781	= .006
Gender (Male/female)	= .365	= .546	= .001	= 1.557	= .186	= .022
Educational level (Low/high)	= 3.291	= .071*	= .012	= 1.301	= .270	= .018
Experimental condition	= 2.183	= .071*	= .030			

* $p<.1$; ** $p<.05$; *** $p<.01$

Repeated measures ANOVA analysis (sphericity violated under Mauchly's test: $\chi(2)=.530$, $p<.001$) shows that mean inequality in overreporting rate over the four texts does not significantly exist (Greenhouse–Geisser: F (2.177, 605.081) = .6, $p=.563$, $\eta^2=.002$). There is also no interaction effect with experimental condition (Greenhouse–Geisser: F (8.706, 605.081) = 1.317, $p=.226$, $\eta^2=.019$), which means there is no statistical proof for effect decay with repeated choices (H6), though, for all conditions but the pen-and-paper condition, mean overreporting rate is highest for the first text (see Fig. 4). Accordingly, UNIANOVA analysis with restructured data (each text's reporting moment as a case) shows a significant decrease in overreporting as time elapsed since signature code submission increases (F (1, 1221) = 93.279, $p<.001$, $\eta^2=.071$), but no interaction with experimental condition (F (4, 1221) = .583, $p=.675$, $\eta^2=.002$), which means no effect decay over time is found (H7).

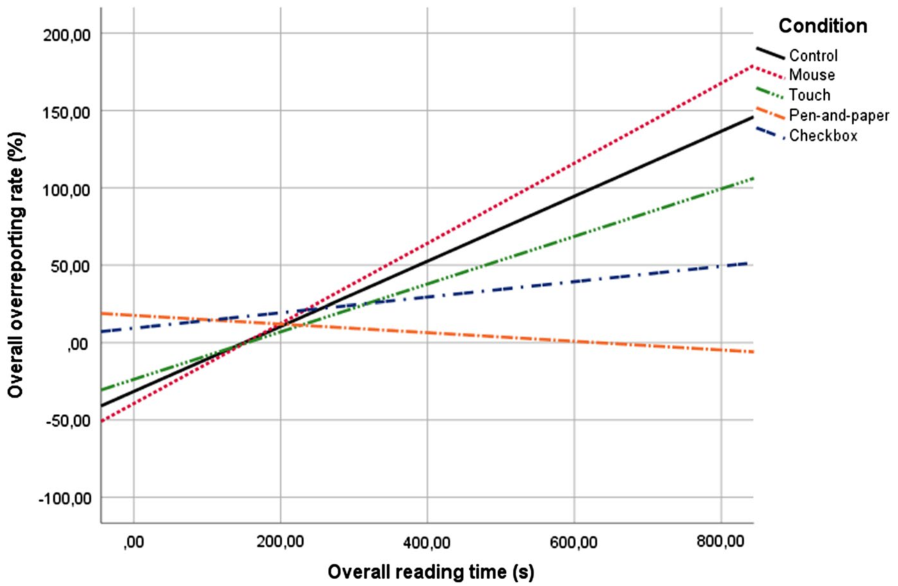

Fig. 3 Overall overreporting rate by overall reading time for each experimental condition (fit line)

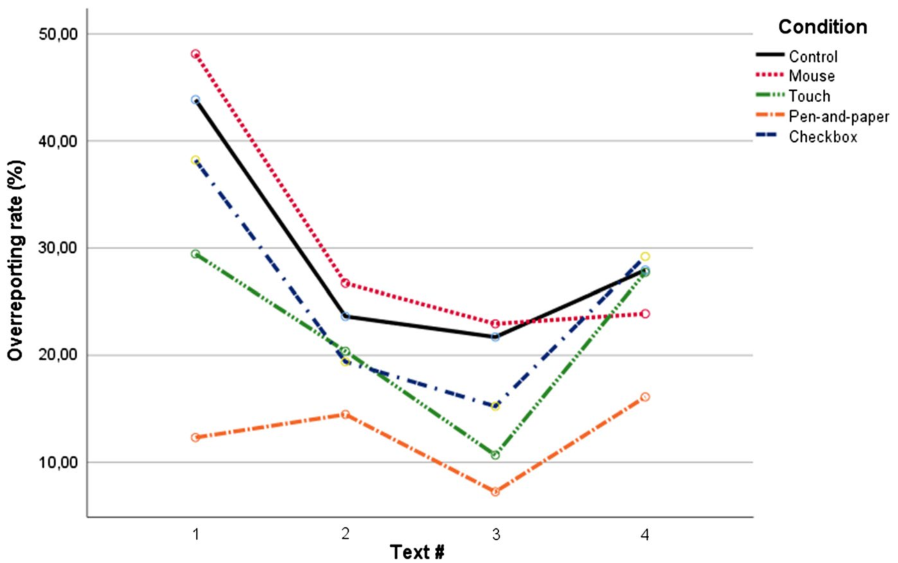

Fig. 4 Overreporting rate per text for each experimental condition

The linear regression analyses for H8 are shown in Table 4. While combining mouse and touch drawn signatures does not lead to any significant results, separating

Table 4 Separate linear regression analysis outcomes for each signature characteristic predicting overall overreporting rate

Signature characteristics	Mouse drawn signatures			Touch drawn signatures			Mouse and touch drawn signatures		
	p	B (sign)	R^2	*p*	B (sign)	R^2	*p*	B (sign)	R^2
Canvas size	= .568	> − .001 (−)	= .005	= .142	< .001 (+)	= .048	= .817	> − .001 (−)	< .001
Pixel number (absolute)	= .064*	= − .002 (−)	= .053	= .070*	= .001 (+)	= .073	= .716	< .001 (+)	= .001
Pixel number (relative)	= .182	= − 5.539 (−)	= .028	= .291	= 3.836 (+)	= .025	= .370	= − 2.481 (−)	= .007
Trim size (absolute)	= .057*	< .001 (+)	= .056	= .009***	< .001 (+)	= .146	= .930	> − .001 (−)	< .001
Trim size (relative)	= .043**	= − .665 (−)	= .064	= .012**	= .975 (+)	= .135	= .303	= − .257 (−)	= .010
Time spent signing	= .956	= .009 (+)	< .001	= .522	= .205 (+)	= .009	= .559	= .083 (+)	= .003
Times cleared	= .825	= − .882 (−)	= .001	= .317	= − 7.605 (−)	= .023	= .791	= − .890 (−)	= .001

* $p < .1$; ** $p < .05$; *** $p < .01$

the two types does. Particularly, in mouse drawn signatures relative trim size is negatively associated with overreporting, while in touch drawn signatures the opposite holds true. Absolute trim size, however, is associated with overreporting for both mouse and touch drawn signatures, though only near significantly for mouse drawn signatures. Greater digital signature size may be associated with dishonesty, but different characteristics show conflicting results (H8).

3.3 Discussion

The results of Experiment 1 do not provide significant proof for any hypothesis. A slight trend, however, shows that touch and pen-and-paper signatures may positively influence honesty. The high cancellation rate among the latter two conditions may have influenced these results, decreasing statistical power and creating a potential self-selection bias.

Additionally, the average overreporting rate in this experiment was 25.41%. In Chou's (2015b) experiment, those in the control condition overreported by 77.36%, and those in the most effective signature condition (mouse drawn) by 58%. An essential difference between both experiments is the sample: Chou's (2015b) experiment was conducted on Amazon Mechanical Turk (MTurk). Prior research shows that MTurk participants are strongly financially motivated (Ipeirotis 2010; Litman et al. 2015) and commonly lie about their characteristics to be eligible for paid tasks (Chandler and Paolacci 2017; Sharpe Wessling et al. 2017). A customer panel could have a different motivation for participation (i.e., helping the organization by providing useful feedback, rather than earning money), which could explain the difference in overreporting. A lower default occurrence of dishonesty may have made it more difficult to find an honesty effect.

4 Experiment 2

The second experiment addresses the limitations of the first experiment, and tests the effect of various digital signatures in a sample of Amazon Mechanical Turk (MTurk) workers.

4.1 Method

4.1.1 Procedure

Adapting a method of Rahwan et al. (2018), but using the die-under-the-cup paradigm Fischbacher and Föllmi-Heusi (2013) instead of a coin toss for increased measurement sensitivity, online participants were asked to play ten rounds of a die roll game. In each round, participants had to roll a die once, and report the outcome. They were allowed to use any die, be it physical or virtual, as long as it were fair and six-sided. When rolling 1 to 5, participants would earn a potential bonus of that number in dollar cents, and when rolling 6 they would earn nothing. The nature of this task allows participants to act dishonestly and claim more bonus than they deserve, while this is, on an individual level but not on the group level, undetectable. Participants were informed that their overall bonus would be compared to that of a random other participant, and if it were equal or higher, they would enter the lottery. One in five participants in the lottery would then be paid their overall bonus. In four attention checks (two regarding the bonus outcome of die rolls and two regarding the conditions for entering the competitive lottery), participants' understanding of the instruction was confirmed.

After the die roll game, following Rahwan et al. (2018), participants filled out a morality scale and were offered the opportunity to donate a percentage of their overall potential bonus payment to one of six charities. Then, they filled out the Single Item Narcissism Scale (Konrath et al. 2014), their financial well-being and digital skills level were measured (using, respectively, the CPFB (2015) Financial Well-Being Scale, and the same digital skills level scale as in Experiment 1, developed by Van Deursen et al. (2014)], and demographic data was collected. Dependent on their condition, they were also asked an additional question about their device input method (see Sect. 4.1.2).

Prior to the die roll game, participants had to certify that the to be submitted information would be correct. Assigned to one of five experimental conditions, this was done by providing a signature or, in the control condition, simply continuing to the next page.

4.1.2 Experimental conditions

The experimental conditions were the same as in Experiment 1 (see Sect. 3.1.2), apart from the previously Dutch message of the checkbox signature being translated to 'I declare to be honest'.

87 participants in the mouse drawn signature condition were recoded to the touch drawn signature condition, of which for 32 touch was detected and 55 reported to have used a touchpad. 47 participants in the touch condition were recoded to the mouse condition, because touch was not detected by the web page and they did not report having used a touchpad.

4.1.3 Sample

MTurk was used for sample recruitment. MTurk is a crowdsourcing platform via which "workers" complete "human intelligence tasks" and get paid for doing so (Amazon, n.d.). It is commonly used in academic research (Chandler and Shapiro 2016), as it can quickly deliver inexpensive, high-quality data and offers a diverse sample that is significantly more diverse than a college sample (Buhrmester et al. 2011). MTurk participants have been found to be more attentive than participants from other pools (Hauser and Schwarz 2016).

After the first 323 participants, cancellation in the pen-and-paper drawn signature condition was high (completed per condition at that time: 103 control, 69 mouse, 60 touch, 15 pen-and-paper, 76 checkbox). Worker reviews of the HIT, as found on Turkopticon (a website where workers share information on MTurk requesters and tasks), revealed that workers may have considered the pay too low for a photo upload task. To address this, the pay was upped from 0.25 $ to 0.50 $. An evaluation of the cancellation rate of 603 participants that were paid 0.50 $ indicated that the measure had an insignificant effect.[4] A final group of 64 participants was recruited under a pay of 0.25 $, with only assignation to the pen-and-paper condition possible.

The final number of participants was 989 (age mean = 34.98, age SD = 11.335, age min. = 18, age max. = 78, male % = 52.3, female % = 47.3, other gender % = .4), with 247 in the control condition, 165 in the mouse condition, 222 in the touch condition, 150 in the pen-and-paper condition, and 205 in the checkbox condition.

4.1.4 Analysis

To test H1 to H5, a UNIANOVA model for overall bonus (DV, continuous), self-reported morality (DV, continuous), and percentage donated (DV, continuous) was formed, with as independent variables the same as in the model of Experiment 1, and added financial well-being (IV, continuous), narcissism (IV, continuous), pay (IV, categorical [0.25/0.50 $]), plus their interaction terms with experimental condition. Similarly, H6, H7, and H8 were tested with the according models from Experiment 1, updated with the relevant new variables.

4.2 Results

Compared to the expected overall bonus (.25 $), based on the outcome distribution of a fair six-sided die, participants' overall bonuses (M = .293, SD = .079) are significantly higher (t (988) = 16.843, $p < .001$, Cohen's $d = .54$), which indicates that dishonesty has taken place. Figure 5 shows the mean overall bonus per experimental condition.

UNIANOVA analysis (displayed in Table 5) shows no significant mean inequality between experimental conditions for overall bonus, self-reported morality, or donation percentage. As such, the interventions have no impact, and all interventions have an equal effect (H1). Age is negatively associated with overall bonus. Additionally, male participants significantly claim more overall bonus than female participants. No other factors are able to significantly predict overall bonus, but higher educated participants donate more to charity than lower educated participants, while, conversely, a higher digital skills level is associated with donating less, but also with higher self-reported morality. Narcissism is associated with lower self-reported morality. Finally, an interaction effect is found between experimental condition and financial well-being on self-reported

[4] Cancellation rate was 69.33% (104 out of 150) under 0.25 $ and 60.92% (145 out of 238) under 0.50 $. A binary two-tailed *t* test showed that this difference was insignificant (t (386) = 1.684, $p = .093$).

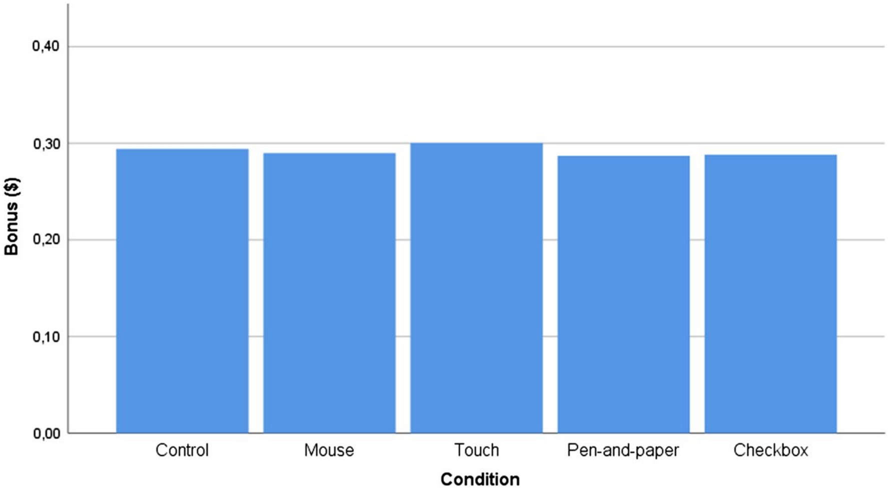

Fig. 5 Mean overall bonus per experimental condition

morality. Under low financial well-being, those in the control condition report lower self-reported morality than those in signature conditions. As financial well-being increases, those in the control condition eventually self-report higher morality (see Fig. 6). Besides this interaction, there is no evidence for participant characteristics affecting the effect of the signature interventions (H2, H3, H4, H5).

Repeated measures ANOVA analysis (sphericity violated under Mauchly's test: $\chi(2) = .919$, $p < .001$) shows that mean inequality in bonus over the ten separate die roll game rounds near significantly exists (Greenhouse–Geisser: F (8.836, 8597.002) = 1.763, $p = .071$, $\eta^2 = .002$). There is, however, no interaction effect with experimental condition (Greenhouse–Geisser: F (35.342, 8597.002) = 1.034, $p = .393$, $\eta^2 = .004$). Furthermore, the bonus means per round do not show a gradual decrease (see Fig. 7). Therefore, there is no evidence for effect decay with repeated choices (H6). Accordingly, UNIANOVA analysis with restructured data (each round's reporting moment as a case) shows a significant decrease of bonus as time elapsed since signature code submission increases (F (1, 9833) = 50.881, $p < .001$, $\eta^2 = .005$), but no interaction with experimental condition (F (4, 9833) = 1.119, $p = .346$, $\eta^2 < .001$), which means no effect decay over time is found (H7).

The linear regression analyses for H8 are shown in Table 6. Relative pixel number is significantly negatively associated with overall bonus for touch drawn signatures. Conflictingly, trim size of touch drawn signatures is significantly positively associated with narcissism. A lack of any other significant relationship between signature size measures and the four dependent variables indicates that digital signature

Table 5 UNIANOVA of participant characteristics and experimental condition (IVs) on overall bonus, self-reported morality, and donation percentage (DVs)

IV	DV	Individual			In interaction with experimental condition		
		F	*p*	η^2	F	*p*	η^2
Financial well-being	Bonus	= .138	= .719	< .001	= .510	= .728	= .002
	Morality	= 1.309	= .253	= .001	= 3.265	= .011**	= .014
	Donation	= .179	= .672	< .001	= .738	= .566	= .003
Digital skills level	Bonus	= .002	= .965	< .001	= .547	= .702	= .002
	Morality	= 33.350	< .001***	= .034	= .656	= .623	= .003
	Donation	= 4.078	= .044**	= .004	= .936	= .442	= .004
Narcissism	Bonus	= .060	= .807	< .001	= 1.039	= .386	= .004
	Morality	= 29.509	< .001***	= .030	= .236	= .918	= .001
	Donation	= 1.371	= .242	= .001	= 1.460	= .212	= .006
Age	Bonus	= 4.614	= .032**	= .005	= .975	= .420	= .004
	Morality	= .045	= .831	< .001	= .411	= .801	= .002
	Donation	= 1.295	= .255	= .001	= 1.272	= .279	= .005
Gender	Bonus	= 5.209	= .023**	= .005	= .391	= .815	= .002
(Male/female)	Morality	= 2.015	= .156	= .002	= 1.607	= .170	= .007
	Donation	= 1.890	= .170	= .002	= .604	= .660	= .003
Educational level	Bonus	= 2.702	= .101	= .003	= 1.281	= .276	= .005
(Low/high)	Morality	= .471	= .493	< .001	= .267	= .899	= .001
	Donation	= 5.840	= .016**	= .006	= .877	= .477	= .004
Pay	Bonus	= .809	= .369	= .001	= .746	= .561	= .003
(0.25/0.50 $)	Morality	= 1.040	= .308	= .001	= .210	= .933	= .001
	Donation	= 3.023	= .082*	= .003	= 1.374	= .241	= .006
Experimental condition	Bonus	= 1.081	= .365	= .005			
	Morality	= .974	= .421	= .004			
	Donation	= .366	= .833	= .002			

* $p < .1$; ** $p < .05$; *** $p < .01$

size may not be of use in predicting narcissism or unethical behavior. Time spent signing is significantly positively associated with overall bonus, but also with donation; times cleared is near significantly positively with narcissism, but also near significantly negatively with overall bonus. Therefore, though (near) significant, these measures do not reach agreement, and digital signature characteristics seem unable to unilaterally predict narcissism or honesty behavior (H8).

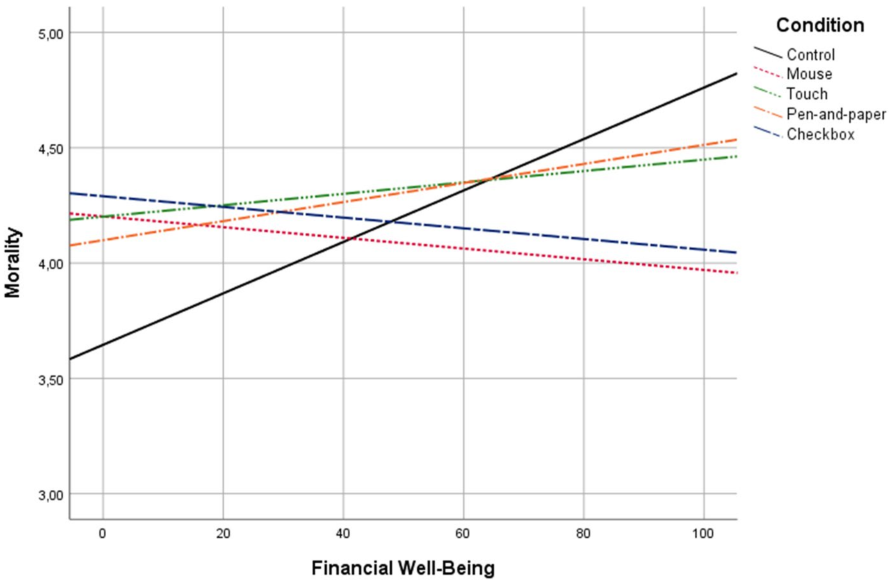

Fig. 6 Self-reported morality by financial well-being for each experimental condition (fit line)

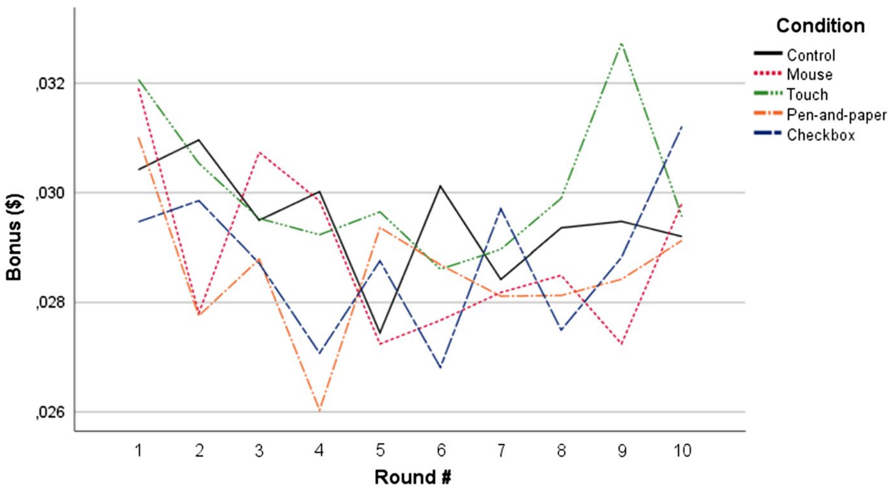

Fig. 7 Mean bonus per round for each experimental condition

Table 6 Separate linear regression analysis outcomes for each signature characteristic predicting narcissism, overall bonus, self-reported morality, and donation percentage

Signature characteristic	Mouse drawn signatures			Touch drawn signatures			Mouse and touch drawn signatures		
	p	B (sign)	R^2	*p*	B (sign)	R^2	*p*	B (sign)	R^2
Canvas size									
Narcissism	= .668	< .001 (+)	= .001	= .287	< .001 (+)	= .005	= .483	> − .001 (−)	= .001
Bonus	= .781	< .001 (+)	< .001	= .394	< .001 (+)	= .003	= .169	< .001 (+)	= .005
Morality	= .452	> − .001 (−)	= .003	= .675	> − .001 (−)	= .001	= .454	< .001 (+)	= .001
Donation	= .183	> − .001 (−)	= .011	= .890	> − .001 (−)	< .001	= .107	> − .001 (−)	= .007
Pixel number (absolute)									
Narcissism	= .708	> − .001 (−)	= .001	= .071*	< .001 (+)	= .015	= .683	> − .001 (−)	< .001
Bonus	= .928	< .001 (+)	< .001	= .691	> − .001 (−)	= .001	= .793	< .001 (+)	< .001
Morality	= .514	> − .001 (−)	= .003	= .377	> − .001 (−)	= .004	= .676	< .001 (+)	< .001
Donation	= .145	= − .001 (−)	= .013	= .772	< .001 (+)	< .001	= .230	< .001 (+)	= .004
Pixel number (relative)									
Narcissism	= .343	= − .116 (−)	= .006	= .174	= .071 (+)	= .008	= .450	= − .039 (−)	= .001
Bonus	= .730	= − .002 (−)	= .001	= .045**	= − .006 (−)	= .018	= .175	= − .003 (−)	= .005
Morality	= .692	= .019 (+)	= .001	= .903	= − .003 (+)	< .001	= .285	= .024 (+)	= .003
Donation	= .165	= − 3.207 (−)	= .012	= .373	= 1.061 (+)	= .004	= .439	= − .805 (+)	= .002
Trim size (absolute)									
Narcissism	= .308	< .001 (+)	= .006	= .030**	< .001 (+)	= .021	= .508	< .001 (+)	= .001
Bonus	= .918	< .001 (+)	< .001	= .401	< .001 (+)	= .003	= .225	< .001 (+)	= .004
Morality	= .229	> − .001 (−)	= .009	= .220	> − .001 (−)	= .007	= .711	> − .001 (−)	< .001
Donation	= .097*	> − .001 (−)	= .017	= .613	< .001 (+)	=.001	= .233	> − .001 (−)	= .004

Table 6 (continued)

Signature characteristic	Mouse drawn signatures			Touch drawn signatures			Mouse and touch drawn signatures		
	p	B (sign)	R^2	*p*	B (sign)	R^2	*p*	B (sign)	R^2
Trim size (relative)									
Narcissism	= .428	= .006 (+)	= .004	= .038**	= .010 (+)	= .019	= .154	= .006 (+)	= .005
Bonus	= .343	< .001 (+)	= .006	= .968	< .001 (+)	< .001	= .619	> − .001 (−)	= .001
Morality	= .674	= − .001 (−)	= .001	= .886	< .001 (+)	< .001	= .965	> − .001 (−)	< .001
Donation	= .145	= − .192 (−)	= .013	= .129	= .174 (+)	= .010	= .703	= − .033 (−)	< .001
Time spent signing									
Narcissism	= .085*	= .014 (+)	= .018	= .666	= .003 (+)	= .001	= .059*	= .010 (+)	= .009
Bonus	= .524	< .001 (+)	= .002	= .033 **	= − .001 (−)	= .020	= .044**	< .001 (+)	= .011
Morality	= .483	= .002 (+)	= .003	= .150	= .004 (+)	= .009	= .197	= .003 (+)	= .004
Donation	= .047**	= .313 (+)	= .024	= .027**	= .303 (+)	= .022	= .002***	=.322 (+)	= .025
Times cleared									
Narcissism	= .099*	= .230 (+)	=.017	= .904	= − .017 (−)	< .001	= .052*	= .190 (+)	= .010
Bonus	= .271	= − .006 (−)	= .007	= .256	= − .009 (−)	= .006	= .085*	= − .008 (−)	= .008
Morality	= .928	= − .005 (−)	< .001	=.741	=.023 (+)	< .001	= .778	= − .012 (−)	< .001
Donation	= .565	= 1.531 (+)	= .002	= .429	= 2.557 (+)	= .003	= .223	= 2.435 (+)	= .004

* $p < .1$; ** $p < .05$; *** $p < .01$

5 General discussion

5.1 Findings

Across two experiments no significant effect of any digital signature was found on subsequent moral behavior. Accordingly there was no evidence for related hypotheses about variation between signature type, the moderating role of individual characteristics, and effect decay. While some signature characteristics were found to have a significant relationship to honesty, self-reported morality, charitable giving, or narcissism, a uniform relation was lacking (with similar measures conflicting within each experiment, and the two experiments not finding evidence for the same measures). Therefore all hypotheses are rejected.

Despite this, the results of the current research do indicate that certain participant variables have a small but significant influence on honesty behavior:

a. In Experiment 2, it appeared that higher age is positively associated with honesty, which is in line with the findings of previous research (e.g., Friesen and Gangadharan 2013; Fosgaard 2016);
b. In Experiment 2, male participants lied more than female participants. The dishonesty literature appears to largely support this finding (e.g., Friesen and Gangadharan 2012; Capraro 2018), though results remain mixed on the gender effect (see review in Jacobsen et al. 2018);
c. Charitable giving was higher among higher educated participants, as has been well-established in previous research on philanthropy (see review in Bekkers and Wiepking 2011);
d. Digital skills level was associated with both higher self-reported morality and donating less. It is theoretically unclear why digital skills level is a predictor herein, though connection between the two dependent variables might be explained by moral balance theory (e.g., Nisan 1991; see also Merritt et al. 2010), considering that morality was reported before deciding upon the donation (an opportunity to restore moral balance);
e. Narcissism was strongly related to lower self-reported morality, but it did not predict actual behavior. That narcissists do not report themselves as more moral than the average person has been previously found (Campbell et al. 2002), but the proposed link between narcissism and fraudulent behavior (see 2.2.3) could not be confirmed;
f. Controlling for educational level and other participant variables in the model, it appeared that participants that spent longer on reading the texts in Experiment 1 also overreported their reading time more (both absolutely and relatively). This phenomenon is perhaps formed via exponentially increased feelings of entitlement (see Poon et al. 2013) as reading time increases, or a cognitive bias of some sort which facilitates the addition of an exponentially increased number as reading time increases.

5.2 Implications

The results support the idea that digital signatures are not equivalent to pen-and-paper signatures in terms of their effectiveness as a psychological tool to promote honesty (Chou 2015a), but bring into question whether drawn types of digital signatures are indeed an exception to that (cf. Chou 2015b). Furthermore, the inclusion of a pen-and-paper signature condition makes for a contrast with the original study of Shu et al. (2012), casting doubt on signature interventions and underlying theory as a whole.

It should be noted that prior to this experiment the number of studies on honesty that experimented with signature interventions in isolation was limited, there being only three studies besides the current (viz., Chou 2015b; Kettle et al. 2017; Shu et al. 2012): despite having gained a large amount of attention, signature interventions were still relatively unestablished as a tool to promote honesty.

The current work, as such, first and foremost served as conceptual replication of the honesty effect of signatures (extending the effect to a digital environment). It set out to then deepen the understanding of the effect, investigating moderating factors and more. Rather than only focusing on the environment (meaning the digital signature interventions) or on the person we focused on both, following an integrated cognitive-ecological approach [as per Gigerenzer and Fiedler (2004) and Fiedler and Wänke (2009)]. Doing this we tried to go beyond the 'one size fits all' approach which is common in nudging. Yet this main effect on honesty, for which there was positive prior evidence and which was a prerequisite for the hypotheses of this research, remained absent.

Since conduction of our digital signature experiments, a series of signature replication experiments has been published (Kristal et al. 2020). In line with our research and that of Kettle et al. (2017), a signature honesty effect could not be replicated. In other words, the original effect found by Shu et al. (2012) and later Chou (2015b) is likely a fluke: a signature does not promote honesty.

These null results are in line with several other studies that display a trend of failed replications in honesty nudging. For instance, Kettle, Hernandez, Sanders, Hauser, and Ruda (2017) experimented with various short messages and tasks that were applied to CAPTCHA pop-up windows before Guatemalan taxpayers filled in an online tax form. They found that the nudges, which were taken from multiple earlier studies, did not enhance honesty. Similarly, Corrigan-Gibbs et al. (2015) found that honor codes, previously proven successful in promoting honesty by Mazar et al. (2008) and Shu et al. (2011), may not have any effect. A mass direct replication by Verschuere et al. (2018) of the well-known Ten Commandments experiment by Mazar et al. (2008) showed no effect, too, and there are more honesty intervention replication studies that show null results (e.g., Howard et al. 2017; Pashler et al. 2013).

The field of moral psychology is therefore certainly not immune to the replication crisis. Though some replication studies do confirm earlier results (e.g., Schild et al. 2019), an increasing doubt now exists about if 'soft' psychological interventions (based on self-concept maintenance) can really promote honesty. We advise policy-makers to consider not only nudging interventions, but also other strategies, i.e., 'boosting' [enhancing people's decision-making competence, see Hertwig and Grüne-Yanoff (2017)] and 'pushing' [altering decision options and/or incentives, see d'Adda et al. (2017)].

5.3 Limitations

The main limitation of this research is the potential self-selection bias due to cancellation at signature submission of which the effect is unclear. Particularly the pen-and-paper condition suffered from this. After completion of Experiment 1, it was hoped that MTurk participants—who were paid for participation—would not show this problem, or at least to a much lesser extent. Unfortunately cancellation rate remained high, even after doubling the payment. The effort that is involved for participants, as well as possible legal and privacy concerns, troubles digital signature experiments. Behavior of those not signing may be quite different from those that do. Future research may be able to avoid this potential bias by increasing participation pay to a great enough extent (which may become quite costly when aiming for a sufficient sample size) or performing an experiment in a setting where signing is mandatory and self-selection is not possible (e.g., in a field experiment in cooperation with a governmental organization).Yet, taking into account the work of Kristal et al. (2020), it seems unlikely that cancellation hindered us from finding a positive effect. Cancellation does show that digital signatures, particularly those that require more effort, are detested by users. We hypothesize that, if cancellation were not possible, a backfiring effect may have been observed—given that the frustration that digital signatures may cause could surge an emotional justification for unethical behavior (see Shalvi et al. 2013).

More minor limitations concern the administration of certain variables, such as measurement of narcissism through the Single Item Narcissism Scale (Konrath et al. 2014). Though validated, it lacks accuracy compared to more elaborate methods of assessing the personality trait [e.g., the multifactor 40-item Narcissistic Personality Inventory (Raskin and Hall 1979)]. Experiment 2 had real financial consequences, but the overall pay was relatively low, which may have played a role in finding no effect of financial well-being on behavior. Similarly, doubling participants' pay had no effect; herein, the limiting factor is that it only concerned an absolute increase of 0.25 $. Finally, unlike Ham et al. (2018), the current model of signature characteristics predicting dishonest behavior did not control for the length of participants' names, which may have caused a reduction in statistical power.

5.4 Conclusion

In sum, digital signatures do not show a positive impact on honesty, regardless of signature type, and no proof was found for the additional hypotheses. As such, policy makers should think twice before implementing digital signatures, particularly those that require more effort and are detested by users. Given our null results and those of other signature honesty studies (Kettle et al. 2017; Kristal et al. 2020) a true effect is unlikely to exist. We therefore suggest not dedicating future research to signature interventions for honesty.

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Availability of data and materials The research data and materials that support the findings of this study are available in the Open Science Framework repository at https://osf.io/z6527/ (https://doi.org/10.17605/osf.io/z6527).

Compliance with ethical standards

Conflict of interest There are no competing interests to be reported.

Ethical standard The procedures of both experiments were approved by the ethical committee of the University of Twente.

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