**Experience with access regime policies influences compliance and enforcement behaviors of common-pool resource users**

**Abstract**

Governance regimes which assign exclusive access to support collective action are increasingly promoted to manage common-pool resources under the premise they foster environmental stewardship. However, experimental evidence linked to existing policies, which explore this premise is lacking. Overlapping access policies in small-scale fisheries provide a unique opportunity to test the effects of access regimes over users' stewardship behaviors. We performed a lab-in-the-field experiment to assess how fishers’ previous experience with access regimes relate to compliance and peer-enforcement (n = 120). Fishers’ compliance and peer-enforcement decisions were compared in a common-pool-resource game. Treatments differed in framing to represent exclusive access and pseudo-open access regimes, both of which fishers face in real life. The highest levels of compliance and peer-enforcement were observed under the exclusive access treatment but only for fishers who have previous successful experiences with exclusive access policies. Results support previous research on ocean governance by experimentally assessing the role of access regimes over users’ stewardship behaviors.

**Introduction**

Environmental stewardship is a promising pathway towards the sustainable use and conservation of natural common-pool resources (CPRs) (Bennett et al. 2018). Local environmental stewardship can trigger the protection and responsible harvest of natural resources averting “the tragedy of the commons” (Ostrom 1990; Bennett et al. 2018). Compliance with appropriation rules and peer-enforcement are stewardship behaviors strongly linked to successful conservation and management outcomes across ecosystems (Ostrom 1990; Rustagi et al. 2010; Bergseth et al. 2015; Wright et al. 2016). Therefore, identifying policies that enhance users’ compliance and peer-enforcement is an important step to advance in the conservation of CPRs. An approach increasingly applied to foster compliance and peer-enforcement amongst CPRs users is the establishment of formal collective exclusive access regimes (CEARs) (Nguyen Thi Quynh et al. 2017). These regimes grant legal rights to a group of users to exclusively access, use, and/or manage resource stocks (Schlager & Ostrom 1992). In theory, CEARs would incentivize environmental stewardship compared to open access (OA) by securing future benefits to those investing in a stock’s sustainability and involving them in decision-making (Jentoft et al. 1998; Wilen et al. 2012).

Achieving sustainability by implementing CEARs rests, in part, on the assumption that formal access rights will promote users’ compliance and peer-enforcement. However, research shows mixed results about the relationship between access regimes policies and local environmental stewardship (Gelcich et al. 2006, 2017; Gilmour et al. 2012; Schroeder & Castillo 2013; Undargaa & McCarthy 2016; McDonald et al. 2020). Mixed results are likely the consequence of case studies encompassing a range of resource systems operating under different institutional and legal settings (van Putten et al. 2014; Gelcich et al. 2019), the lack of counterfactuals (van Putten et al. 2014), and the reliance on self-reported behaviors prone to biases, especially when involving sensitive behaviors such as compliance (Gavin et al. 2010). Experimental economics provides a complementary approach to assess the determinants of human behaviors by controlling for confounding variables (Smith 1982; Ostrom 2006). Moreover, by attaching financial consequences to decisions, economic experiments reduce the biases inherent to self-reporting (Smith 1982). CPR games recreate the collective action problem faced by natural resource users. Insights from lab-in-the-field experiments using CPR games have increased the robustness of findings from case studies and have helped uncover the role of different institutional arrangements in CPR use (Ostrom 2006; Cardenas 2011). Behaviors displayed by users in these experiments have also proven to relate to real-life observations supporting the external validity of this approach (Rustagi et al. 2010; Carpenter & Seki 2011; Gelcich et al. 2013; Basurto et al. 2016). Accordingly, lab-in-the-field experiments constitute an appealing methodology to unpack the relationship between access regimes and local environmental stewardship.

Small-scale fisheries are CPRs for which compliance and peer-enforcement are particularly important given the difficulty to establish effective central management and enforcement (Costello et al. 2012; Donlan et al. 2020). Small-scale fisheries can be managed through different and overlapping access regimes, depending on the different target species, and therefore provide a unique opportunity to test the role of access policies over fishers’ behavior. In central Chile, fishers operate in at least two distinct fishery management access regimes. A CEAR which takes the form of Territorial User Rights for Fisheries (TURFs) granted to fishers’ associations to harvest benthic resources (Gelcich et al. 2010) and a pseudo-OA regime for demersal fish species. Here, we empirically assess how Chilean fishers’ experience with formal CEARs relates to compliance and peer-enforcement using a between-subjects lab-in-the-field experiment. The experiment consisted of CPR games conducted under two treatments that involved the same monetary incentives but differed in framing. In the CEAR treatment, the game was framed as the harvest “loco” (*Concholepas concholepas*) which is harvested within TURFs (Gelcich et al. 2010). In the pseudo-OA treatment, the game was framed as the fishing of hake (*Merluccius gayi*) which is fished in a quota scheme that operates as *pseudo*-OA due to poor enforcement and unclear stock boundaries (Plotnek et al. 2016; Oyanedel et al. 2020). We also considered two types of fishers’ associations depending on their real-life performance with CEAR – high-performance and low-performance.

Assuming self-interested, rational behavior, the predicted outcomes for the game are no compliance and no peer-enforcement. However, deviations from self-interested, rational behavior are common in social dilemmas like CPRs due to subjects’ internalized expectations and motivations (Cárdenas & Ostrom 2004; Rustagi et al. 2010; Ellingsen et al. 2012; Leibbrandt et al. 2013; Bouma & Ansink 2013; Fehr & Schurtenberger 2018). Based on the premise that exclusive access favors the internalization of environmental stewardship, we expect compliance and peer-enforcement to be higher under the CEAR treatment than under the *pseudo*-OA treatment, at least for high-performance associations. If our experiment is externally valid, we also expect high-performance associations to exhibit more compliance and peer-enforcement than low-performance associations under the CEAR treatment. We additionally explore the effects of peer-enforcement over compliance.

**Methods**

***Implementation***

Fishers were recruited from fishers’ associations that (i) targeted both loco and hake, (ii) were located less than 200 km apart to minimize geographical differences (**Fig. S1**), and (iii) could be categorized ex-ante depending on their real-life performance with CEAR – high-performance and low-performance. A total of 120 fishers from two high-performance and three low-performance associations participated in our experiments. Associations were categorized as having high or low performance with CEARs according to a TURF-performance index developed by Marín et al. (2012). The index includes indicators of fishers’ pride in their TURF, compliance with TURF rules, trends of annual TURF catch allowed by authorities, and third-party assessments of TURF management (**Table S1**). All these variables are related to collective action in TURF management. We conducted 12 sessions, two in each association (one with each frame) except for one high-performance association in which we conducted four sessions (two with each frame). **Table 1** summarizes our experimental design.

In each experimental session, 10 fishers from the same association entered the room and seated in front of an individual laptop. A facilitator informed the subjects that they will play 20 rounds of a CPR game in fixed groups of five, randomly and anonymously assembled by the software. Subjects were also informed that decisions would be recorded anonymously and that they could leave the experiment at any moment. After the instructions were read (Supplementary Information), subjects played three trial rounds. Game instructions were identical for both treatments except for the words used to describe the resource units (i.e. number of locos/ kilos of hake), the action (i.e. harvesting/ fishing), and the enforcement authority (i.e. the association’s board/ the National Service of Fisheries) (see the Supplementary Materials). The game was programmed in z-Tree (Fischbacher 2007) and communication during the game was not allowed. Once a session was completed, fishers left the room to receive their payoffs in private while the next group entered the room, thus avoiding communication. We obtained informed consent from all participants. Our protocol was approved by the ethics committee of Pontificia Universidad Católica de Chile.

***The common pool resource game***

***The non-enforced stage***

At the beginning of each round, each fisher was endowed with 100 units of the resource representing their individual quota which was assumed to be harvested completely. Then, simultaneously, each fisher had to privately decide the number of units to harvest above their quota (i.e. overharvest). There was a negative externality to mimic the cost that overharvest imposes on other users in real life. For each unit that a fisher decided to overharvest, each other member of their group lost half a unit. The unitary price of a unit was $10 CLP. The individual payoff per round was given by:

This payoff function generated tension between the individual and the group’s interest. Assuming self-interested, rational behavior, each subject would have maximized their expected payoff by overharvesting as many units as possible. Therefore, the unique equilibrium was a tragedy of the commons in which every subject overharvest 50 units in every round (Gelcich et al. 2013). In this stage of the game, there was no enforcement of the quota, and fishers could overharvest without being punished. Once all subjects entered their decisions, a summary screen revealed to each fisher their total harvest, the mean harvest of other group members, how many units they lost due to others’ overharvest, and their accumulated payoffs.

***The peer-enforced stage***

At the beginning of the 11th round, a peer-enforcement mechanism was introduced unexpectedly and permanently. In the remaining rounds, once all fishers had entered their overharvest decisions, two fishers were randomly assigned as inspectors and randomly and anonymously matched with another group member to be inspected. The harvest of the inspected fisher was revealed to their inspector, and if overharvest was above zero, the inspector had the opportunity to report the offender. Once an offender was reported, their harvest for the round was seized. This mechanism recreates fishers’ real-life decision on whether to report non-compliance to authorities. Once inspectors entered their decisions, a summary screen revealed to each fisher their harvest, others’ mean harvest, the number of units lost due to others’ overharvest, their earnings, and whether their harvest was seized due to a peer’s report.

To recreate the payment a fisher would earn for patrolling, we automatically added $250 CLP to a fisher’s account each time they were appointed as inspectors. Because reporting a peer is costly in real life, inspectors had to pay $250 CLP to report. Assuming rational, self-interested behavior, fishers would not engage in costly peer-enforcement (Yamagishi 1986). Thus, the equilibrium for the peer-enforced stage was also a tragedy of the commons.

***Statistical Analysis***

We operationalized compliance as the percent of resource units that were not overharvested (i.e. an overharvest decision of 50 units corresponded to 0% compliance and an overharvest of 0 units to 100% compliance). Peer-enforcement was assessed as the probability of reporting (i.e. the number of reports over the number of opportunities to report). We used a non-parametric approach with analyses ran over observations aggregated at the individual level. We additionally applied a parametric approach which provides greater power to test whether our main results hold when observations are aggregated at the group level in every round.

To test differences in compliance we ran pairwise comparisons of the individual percent of compliance between treatments for each association type, between association types under each treatment, and between stages for each treatment-association-type combination. To test differences in peer-enforcement we ran pairwise comparisons of the individual probability of reporting between treatments for each association type and between associations types under each treatment. Finally, we ran pairwise comparisons of the individual percent of compliance between the first and the last round in each treatment-stage-association-type combination to evaluate changes in compliance within a stage of the game. We used the Wilcoxon test with two-sided hypotheses testing for each comparison. P-values were adjusted for multiple hypotheses testing within each set of comparisons using the Bonferroni correction method considering a significance level equal to 5%.

Our parametric approach corresponded to the use of two sets of ordinary least squared (OLS) regressions with robust SEs for (i) compliance and (ii) peer-enforcement. The independent variable for (i) was the group percent of compliance in each round and for (ii) was the group probability of reporting in each round. We built multiple models for (i) and (ii) that sequentially included blocks of relevant explanatory variables. This allowed us to check for the stability of coefficients across specifications and to disaggregate the effects of interacting variables. Explanatory variables used in (i) included dummy variables for the CEAR treatment, high-performance associations, and the peer-enforced stage, continuous variables to enumerate the rounds in the non-enforced and peer-enforced stages (from 0 to 9), and relevant interactions of these variables. For (ii), explanatory variables included dummy variables for the CEAR treatment, low-performance associations, and high-performance associations. We also included two control variables — a variable enumerating the round of the peer-enforced stage (from 0 to 9) and the mean overharvest observed by inspectors in each group and round. We only discussed effects that were consistent across model specifications and reported the results of the most parsimonious models for (i) and (ii) in the main text, which were selected based on Akaike’s information criterion. Data and code are available at https://github.com/xxxxxxxx.

**Results**

***Differences in compliance***

As hypothesized compliance was higher under the CEAR treatment than under the pseudo-OA treatment (**Fig. 1**). This difference was significant only for high-performance associations which presented a mean individual percent of compliance of 72% under the CEAR treatment and of 44% under the *pseudo*-OA treatment (Wilcoxon signed-rank test, W = 238.5, adjusted p-value < 0.01, n = 60). In the case of low-performance associations, the mean individual percent of compliance was 57% and 49% under the CEAR and pseudo-OA treatments, respectively, with no statistically significant differences (**Table S2**).

Strategies of players that choose to comply in every round (i.e. overharvest zero in every round) are particularly revealing regarding motivations towards compliance. Therefore, we assessed the effect of treatment on the frequency of this strategy. We found that in high-performance associations, 10 subjects choose to comply in every round under the CEAR treatment and only two applied this strategy under the pseudo-OA treatment (Fisher exact test, adjusted p-value = 0.042, n=60). This difference was not significant in low-performance associations in which only two subjects complied in every round under the CEAR treatment and one under the pseudo-OA treatment.

Differences in compliance between high- and low-performance associations under the CEAR treatment reflected real-life differences regarding success with CEAR. The mean individual percent of compliance was significantly higher in high-performance associations compared to low-performance associations under the CEAR treatment (**Fig. 1**, Wilcoxon signed-rank test, W = 2,371.5, adjusted p-value = 0.02, n= 60) but not under the *pseudo*-OA regime treatment (**Table S2**).

The most parsimonious OLS model showed that the mean group percent of compliance was almost 20% higher in high-performance associations under the CEAR treatment compared to the *pseudo*-OA treatment as well as to compared to the mean group percent of compliance for low-performance associations under both treatments (CEAR × High-perf. association = 19.81, p <0.001, 95% CI [10.66 – 28.96] in Model 5, **Table S3**).

***Differences in peer-enforcement***

Treatment effect on peer-enforcement also matched hypothesized outcomes since peer-enforcement was higher under the CEAR treatment than under the *pseudo*-OA treatment (**Fig. 2**). However, statistical differences were less clear than for compliance behavior. For high-performance associations, the mean individual probability of reporting was 0.70 under the CEAR treatment and 0.41 under the *pseudo*-OA treatment. This difference was significant but did not survive correction for multiple hypotheses testing (Wilcoxon signed-rank test, W = 215.5, p-value = 0.027, adjusted p-value = 0.11). In the case of low-performance associations, the mean individual probability of reporting was 0.31 and 0.18 under the CEAR and the *pseudo*-OA treatments, respectively with no significant differences between treatments (**Table S4**).

Differences in peer-enforcement between association types also reflected real-life differences with CEAR. The mean individual probability of reporting under the CEAR treatment was significantly higher in high-performance associations compared to low-performance associations (**Fig. 2**, Wilcoxon signed-rank test, W = 487.5, adjusted p-value = 0.008). In the case of the *pseud*o-OA treatment, differences between association types did not survive correction for multiple hypotheses testing (Wilcoxon test, W = 548.5, p-value = 0.033, adjusted p-value = 0.132).

The most parsimonious OLS models revealed that the group probability of reporting was significantly higher under the CEAR treatment for high-performance associations compared to the other treatment-association-type combinations (CEAR × High-perf. asso. = 0.24, p <0.05 in Model 5; negative and significant coefficients “Pseudo-OA × High-perf. asso.”, “CEAR × Low-perf. asso.”, and “Pseudo-OA × Low-perf. asso.” in Model 7, **Table S5**). This analysis also showed that in groups of fishers from high-performance associations the probability of reporting was marginally higher independent of the treatment (High-performance asso. = 0.13, p =0.09, 95% CI [-0.01, 0.27] in Model 5, **Table S5**).

***The effect of peer-enforcement on compliance***

There were no significant differences in the mean individual percent of compliance between the non-enforced and the peer-enforced stages for any of the association types under any of the treatments (**Table S2**). Nonetheless, peer-enforcement averted the decline of compliance under the CEAR treatment for high-performance associations (**Fig. 3**). In the case of high-performance associations under the CEAR treatment, the mean individual percent of compliance was 80% in the first round of the non-enforced stage and significantly declined to around 60% to the end of the non-enforced stage (Paired samples Wilcoxon test comparing the first and the last round in the non-enforced stage, W = 147, p-value adjusted <0.001, n=60). In the peer-enforced stage, however, high-performance associations under the CEAR treatment restored high levels of compliance which remained unchanged until the end of the game (**Table S6**). No significant changes in the mean individual percent of compliance occurred under the pseudo-OA treatment for high-performance associations (**Table S6**). There were also no significant changes in the mean individual percent of compliance during any of the stages for low-performance associations under any of the treatments (**Table S6**).

A marginally significant decline in compliance in the non-enforced stage was confirmed by the most parsimonious OLS model with observations aggregated at the group level (Non-enforced rounds = -1.10, p <0.06, 95% CI [-2.25, 0.05] in Model 5, **Table S3**).

**Discussion**

Identifying policy levers to promote local environmental stewardship amongst CPRs users is necessary to prevent natural resource degradation in the absence of effective central enforcement. We provide evidence that access policies governing resource extraction can influence users’ compliance and peer-enforcement. We showed that fishers who have experienced effective management under CEAR displayed higher stewardship in a CPR game framed as the harvest of loco, which operates under CEAR in real life, than in the same game framed as the fishing of hake, which operates under pseudo-OA. While this result supports the role of formal CEARs in promoting CPR users’ stewardship behaviors, our results also highlight that CEARs alone do not guarantee the internalization of environmental stewardship. This is confirmed by the low compliance and peer-enforcement displayed by low-performance associations under the CEAR treatment.

Our results provide experimental support to previous observations that suggest that CEAR policies motivate fishers’ local stewardship (Gelcich et al. 2010; McDonald et al. 2020). We found that for the same group of users, compliance and peer-enforcement increased under the CEAR treatment relative to the pseudo-OA treatment. Our experimental approach takes care of potential selection biases which have raised concerns in previous studies that compared stewardship behaviors across access regimes using different samples (van Putten et al. 2014). Even though we cannot establish a causal link between formal CEARs and increased local stewardship our results suggest a role in shaping users’ incentives towards stewardship. Similar results from lab-in-the-field experiments support the broader idea that the institutions that people face in their daily activities shape their preferences for collective action (Cárdenas & Ostrom 2004; Leibbrandt et al. 2013; Bouma & Ansink 2013).

Differences in behaviors observed in our experiment are arguably influenced by the expectations and norms that different fishers hold under each access regime. For example, the levels of compliance observed in the first round suggest that the highest expectations about others’ compliance occurred in high-performance associations under a CEAR treatment. On expecting high compliance from other group members, these fishers started with high levels of compliance in accordance with common reciprocation principles (Fehr & Schurtenberger 2018). These expectations of high compliance are likely shaped by these fishers’ real-life experience harvesting loco under effective CEAR (Cárdenas & Ostrom 2004). However, compliance eroded in the non-enforced stage as fishers used feedback from the game to update their expectations about others’ behavior (Fehr & Schurtenberger 2018). Similar framing effects on expectations have been reported in the experimental economics literature (Ellingsen et al. 2012).

Despite being at odds with standard self-interested theories of behavior, several fishers incurred in peer-enforcement, as it is commonly observed in social dilemmas such as CPRs games (Yamagishi 1986; Fehr & Schurtenberger 2018). Peer-enforcement did not affect mean levels of compliance for any of the associations under any of the treatments. This is probably due to subjects anticipating and observing a low probability of being sanctioned (less than 0.5) in every treatment-association-type combination except subjects from high-performance associations playing under the CEAR treatment. In which case, a high probability of being sanctioned was key to avert the decline of compliance initially observed in the non-enforced stage. This result goes in line with multiple observations from the lab and the field that have underscored the role of peer-enforcement in sustaining collective action (Ostrom 1990; Rustagi et al. 2010; Wright et al. 2016).

It has been argued that people tend to engage in costly punishment when they perceived that social norms are being violated (Fehr & Schurtenberger 2018). This would suggest that the high levels of peer-enforcement observed for high-performance associations under the CEAR treatment reflect strong norms of cooperation which are expected under effective CEAR management (Ostrom 1990; Jentoft et al. 1998). This is supported by the fact that the highest number of fishers that complied in every round was observed under the CEAR treatment for high-performance associations. Treatments did not differ in monetary incentives and strategic behavior cannot explain complete restraining from overharvesting. Thus, differences in the number of fishers that complied in every round are likely reflecting differences in non-monetary incentives across treatments. Indeed, recent evidence shows that non-monetary motivations predict low levels of quota compliance in the hake fishery in Chile (Oyanedel et al. 2020). Non-monetary incentives in social dilemmas are highly determined by social norms that are sensitive to framing (Krupka & Weber 2013; Bouma & Ansink 2013).

The framing effect that we attribute to the access regime represented in the game could be confounded by other differences between the fisheries used to frame the game. For example, differences in decisions between frames could be due to population dynamics or life-history traits of hake and loco. However, if only differences in resource characteristics were causing changes in users’ behavior, we would have observed the same patterns in both association types. The fact that we observed differences between treatments only in associations that have shown signs of successful CEAR management in real life, indicates that access regimes play a role in explaining the differences observed between treatments.

Our results highlight that framing is a crucial design feature of lab-in-the-field experiments (Alekseev et al. 2017). Social norms are context-specific, and are unconsciously activated by situational cues (Cárdenas & Ostrom 2004; Krupka & Weber 2013; Gelcich et al. 2013; Bouma & Ansink 2013). Framing increased subjects’ familiarity with the decision task and provided the situational cues for the norms that were in place under the different regimes. Therefore, its consideration allowed to design the experiment and interpret results. Our study also contributes to the literature supporting the external validity of lab-in-the-field experiments since performance under CEAR in real life correlated to stewardship behaviors displayed in the game (Rustagi et al. 2010; Carpenter & Seki 2011; Gelcich et al. 2013; Basurto et al. 2016).

The implementation of formal CEARs is a promising approach to respond to the current call for a sustainable and equitable blue economy (Bennett et al. 2019). Fishers in our study showed increased compliance and enforcement under CEAR. Yet, lab-in-the-field experiments also stress that formal CEARs do not guarantee intended behavioral change. Identifying further conditions that favor stewardship under formal CEAR is crucial to guide the design of access regimes that can promote the sustainable use of natural CPRs.

**Supporting Information**

The supporting information document contains a more in detailed description of the categorization into high- and low-performance associations, the instructions of the common-pool resource game, and the following material:

* **Fig. S1**. Location of sampled associations
* **Table S1**. Variables considered to assess association’s performance
* **Table S2.** Non-parametric comparisons of the individual percent of compliance
* **Table S3.** Results of OLS regression models on the group percent of compliance per round
* **Table S4**. Non-parametric comparisons of the individual probability of reporting
* **Table S5**. Results of OLS regression models on the group probability of reporting per round
* **Table S6**. Non-parametric comparisons of the individual percent of compliance within stages

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**Tables**

**Table 1**. Experimental design

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatment**  **Association type** | **Collective exclusive access regime**  **(Loco)** | | ***Pseudo-*open access**  **(Hake)** | |
| **Non-enforced stage**  **(First 10 rounds)** | **Peer-enforced stage (Last 10 rounds)** | **Non-enforced stage**  **(First 10 rounds)** | **Peer-enforced stage (Last 10 rounds)** |
| **High performance** | 30 (six groups of five players) | | 30 (six groups of five players) | |
| **Low performance** | 30 (six groups of five players) | | 30 (six groups of five players) | |

**Figure legends**

**Fig 1.** Mean percent of compliance under the collective exclusive access treatment (blue bar) and the *pseudo*-open access treatment (red bar) for high-performance associations (to the left) and low-performance associations (to the right). Error bars represent the 95% confidence intervals computed at the individual level (n=30).

**Fig 2.** Mean probability of reporting under the collective exclusive access treatment (in blue) and the *pseudo*-open access treatment (in red) for high-performance associations (to the left) and low-performance associations (to the right). Error bars represent the 95% confidence intervals computed at the individual level. Sample sizes differ since the inspector role was randomly assigned in each round and inspectors could only report if the inspected fisher had overharvested. Therefore, not every fisher had an opportunity to report (for high-performance associations under collective exclusive access treatment, n = 22; for high-performance associations *pseudo*-open access treatment, n = 30; for low-performance associations under collective exclusive access treatment, n = 30; for low-performance associations under *pseudo*-open access treatment, n = 28).

**Fig. 3.** Evolution of the mean percent of compliance under the collective exclusive access treatment (blue line) and the *pseudo*-open access treatment (red line) for high-performance associations in the early (rounds 1,2, and 3), mid (rounds 4,5,6, and 7) and late (rounds 8, 9, and 10) periods of the non-enforced and peer-enforced stages (left panel) and for low-performance associations (right panel). Error bars represent the 95% confidence intervals computed at the individual level (n = 30).

**Figures**

**A close up of a logo

Description automatically generated**

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A screenshot of a cell phone

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A screenshot of a cell phone

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