Stackelberg in the Lab: The Effect of Groups and Cooling-Off Periods*

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Abstract

We experimentally investigated the effect of two-person decision-makers (as oppose to individual decision-makers) and 10-minute cooling-off periods for the second movers in a Stackelberg quantity-setting game. Psychological theories suggested that more competitive and profit-maximizing play with group decision-makers and cooling-off periods. The data, however, do not support the theories as we found no evidence of more competitive play for two-person groups; 10-minute cooling-off periods we found, on the other hand, lead to less competitive play.

1 Introduction

> "Experimental economics has focused primarily on the behavior of individual subjects...This may limit the external validity of the experimental results because many important economic decisions are made by small groups such as families, boards of directors, and committees rather than individuals." Cox (2002)

The Stackelberg model is a fundamental, and frequently applied, model of sequential oligopolistic output competition. The subgame perfect equilibrium (SPE) of the Stackelberg duopoly prescribes that the second moving firm will choose an output level, in response to the output level of the first moving firm, that maximizes profit.

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The first moving firm, anticipating the profit maximizing response of the second moving firm, will choose the output level that maximizes profit. The predicted outcome of the Stackelberg model with symmetric firms is asymmetric with the first moving firm producing a larger output level and earning larger profits, relative to the second mover; a phenomenon referred to as the first mover advantage. However, the results from previous experimental investigations of the Stackelberg model are, in general, inconsistent with the model's predictions (Huck, Müller, and Normann (2001) (HMN) and Huck and Wallace (2002) (HW)). In particular, HMN find that first movers fail to exploit their first mover advantage by producing lower than predicted output levels; Additionally, second movers respond by choosing output levels that fail to maximize profits. In a follow-up paper, HW implememt the strategy method for second mover and find similar results to HMN.[1]

The decision making environment used to test the Stackelberg model in HMN an HW featured individual decision makers acting as firms and very little time for deliberation or cooling-off between decisions.[2] In this paper, we experimentally test the effect of group decision making and cooling-off periods in the Stackelberg duopoly considered in HMN and HW. We hypothesize that both group decision making and cooling-off periods will lead to more profit maximizing Stackelberg behavior, which in turn will lead to outcomes that are more consistent with the SPE predictions. To test these hypotheses, we consider an experimental Stackelberg duopoly using a lab environment that is augmented along the following two dimensions: (1) the *firm* decisions are made by 2-person groups, and (2) the second moving *firms* make their decision after a 10 minute cooling-off period.

Both HMN and HW cite social preferences and/or emotional motivations as plausible explanations for the inconsistency between observed behavior in the lab and the predictions of the model.[3] Additionally, HW cite reciprocity as a plausible explanation of the observed non profit maximizing responses by the second movers.[4] The

[1] Endogenous timing variation of the Stackelberg model (Hamilton and Slutsky (1990)) have also been tested experimentally and the results are also, in general, inconsistent with the theoretical predictions (see Huck, Müller, and Nornamm (2002), Fonseca, Huck and Normann (2005), and Fonseca, Müller, and Normann (2006)).

[2] We want to emphasize here that the environment used by HMN and HW is prototypical of what Harrison and List (2004) would consider a "conventional lab experiment". In that regard, this paper is by no means intended as an indictment of the protocol implemented by HMN, and should not be interpreted as such.

[3] Lau and Leung (2006) re-examine the data from HMN (2001) and show that the data is consistent with a simplified version of the Fehr and Schmidt (1999) model of inequity aversion. Specifically, the authors find that more than 1/3 of the subjects exhibit disadvantageous inequity aversion.

[4] The authors note that second movers "quite calmly plan to punish leaders in case they try to exploit their strategic adavantage and, at the same time, they are willing to not to exploit cooperative moves by the leader" (pp. 1). Although the authors do not explicitly refer to these behavioral patterns by the second movers as reciprocity, this type of motivation by the second

results from a growing body of experimental literature suggest that both group decision making and cooling-off periods can mitigate the influence of social preferences and emotions in decision making, which leads to more *selfish* behavior. A thorough discussion of this literature, including references, is presented in the subsequent section. Here, the term selfish is used to describe behavior characterized by maximizing own material payoffs. In the context of a Stackelberg model, selfish decision making corresponds to profit maximizing decision making, which implies that group decision making and cooling-off periods will result in Stackelberg behavior that is more consistent with the SPE prediction. Hence, the motivation of this study to investigate the effect of group decision making and cooling-off periods in an experimental Stackelberg game.

As an additional motivation, we contend that group decision making and cooling-off periods are representative characteristics of firm decision making environments in the field. It is well documented that firm decisions are likely to be discussed (formally or informally) and jointly decided upon by a committee of executives that might include the CEO, CFO, COO, and/or the board of directors, e.g., Cason and Mui (1997), Messick, Moore, and Bazerman (1997), Cox (2002), and Kocher and Sutter (2005). Similarly, firm decisions are likely to be made after a period of careful consideration and deliberation. This deliberation period allows executives the time to carefully think through the decision, and provides time for emotional motivations of the executives to "cool-off". Group decision making and deliberation or cooling-off periods ensure that the decisions made by the firm are carefully considered and in the best interest of the firm, i.e., maximize profit. By implementing group decision making and cooling-off periods, we create a lab environment that in more representative of firm decision making environments in the field. We hypothesize that this, in turn, will lead to decisions in the lab that are carefully considered and in the best interest of the "firm", i.e., maximize payoffs.

Laboratory experiments provide a controlled environment and, as a result, are a useful research tool for gaining valuable insights regarding behavior in naturally occurring economic environments. However, one of the concerns with lab experiments is the limited extent with which the results from the lab can be extrapolated to behavior in the field. Levitt and List (2007) note that "perhaps the most fundamental question in experimental economics is whether findings from the lab are likely to provide reliable inferences outside of the laboratory" (pp. 170); A concept Levitt and List refer to as the *generalizability* of a lab experiment.[5] We assert that the generalizability of lab results relating to firm behavior is particularly tenuous due to the differences in the decision making environment between the lab and the field,

mover is consistent with the notion of reciprocity later modeled by Dufwenberg and Kirchsteiger (2004). Hence, I refer to this type of second mover behavior as reciprocity.

[5]Other terms have been used in reference to the extrapolation of lab results to the field, including *external validity* (Campbell and Stanley (1963)) and *parallelism* (Wilde (1981) and Smith (1982)).

which include the size of the decision making unit and the length of the deliberation period between decisions.[6]

Gneezy and List (2006) argue that, "before we can begin to make sound arguments that behavior observed in the lab is a good indicator of behavior in the field, we must explore whether certain dimensions of the laboratory environment might cause differences in behavior across these domains" (pp. 1381). We take a first step, in regards to the Stackelberg model, by investigating the effect of group decision making and cooling-off periods in the lab. We contend that both characteristics are representative of firm decision making environments in the field, and thus a better approximation of firm decision making environments in the field. Although we specifically study an experimental Stackelberg duopoly, the results from this study can provide insights regarding the effect of group decision making and cooling-off periods in other experiments related to firm specific decisions. Thus, as a broader methodological contribution, we hope this study can be informative for developing protocols that can increase generalizability of future experiments relating to firm specific models, e.g. entry, pricing, R & D, and advertising.

The paper proceeds by discussing relevant literature and developing research hypotheses in Section 2. We present the experimental design in Section 3. The results are presented in Section 4, and Section 5 concludes with discussion.

2 Related Literature

2.1 Group Decision-making

The literature focusing on group decision-making and the comparison with individual decision-making is extensive and spans many disciplines including economics and social psychology. Many of the experimental studies find significant differences between group behavior and individual behavior. Despite that fact that many important economic situations involve groups as decision makers; most of the experimental studies consider only individual decision makers.

The results from prior experimental studies suggested that groups do exhibit more self-interested behavior than individuals. For example, Bornstein, Kugler, and Ziegelmeyer (2004) considered a centipede game. They found that groups chose to end the game at an earlier stage than individuals in both the increasing and constant sum versions of the game. That is, groups appear to exhibit behavior that is "closer" to the game theoretic predictions. Kocher and Sutter (2005) and Sutter

[6] We are by no means implying that the size of the decision making unit and the length of the deliberation period between decisions fully exhaust the set of differences between firm environments in the lab and in the field. We refer the reader to Harrison and List (2004) and Levitt and List (2007) for a discussion of other characteristics along which the lab and the field differ.

(2005) found that small groups choose smaller numbers and outperform individuals in an experimental guessing game. In addition, as the game is repeated, groups exhibited increased depth of reasoning. Cooper and Kagel (2005) considered several versions of a limit pricing signaling game. They found that groups exhibited more competitive behavior than individuals. In addition, the difference in strategic behavior between groups and individuals increases as the complexity of the game increases. Bornstein and Yaniv (1998) consider and ultimatum game and find that groups demanded more than individuals. Kugler, Bornstien, Kocher, and Sutter (2007) find that senders sent less in a trust game and Cox (2002) find that groups returned less in a trust game. Kocher and Sutter (2007) find that groups transfer less in a gift exchange game.

The literature comparing the decision making of groups and individuals is extensive. However, comparing the decision of groups against individuals in a Stackelberg game has yet to be explored. The previous experimental literature suggests that group decision makers may be less motivated by other regarding preferences compared to individual decision makers.[7] Considering that the decision-making of firms is likely to be made by groups, we argue that the results from individual-level Stackelberg experiments may not generalize to firm behavior. Hence our motivation to reexamine the Stackelberg model using small groups as decision makers.

2.1.1 Research Hypotheses

Several studies from social psychology suggest that groups behave more competitively than individuals. Insko et al. (1987, 1998, 1990, 1994) investigated differences between groups and individuals in Prisoners Dilemma games. The experimental findings suggest that groups behave much more competitively than individuals; a phenomenon they denote as the discontinuity effect. Insko et al. (1987) provided two possible explanations for the discontinuity effect: (1) the "social support of self-interested competitiveness" hypothesis and (2) the "schema-based distrust" hypothesis. The former suggests that groups provide their members with support for acting in a self-interested, or rational, manner, whereas individuals have no access to such support. Social support may help to overcome pressures from social norms of fairness, equity, and reciprocity. The latter argues that groups form beliefs that other groups will behave more competitively or aggressively. The schema-based distrust hypothesis posits that groups perceive other groups to be more competitive, and thus are more competitive themselves.[8]

[7] There exists one notable exception. Cason and Mui (1997) find that groups behavior was less "rational" i.e. more other regarding in a dictator game. However, Luhan, Kocher and Sutter (2009) replicated the design of Cason and Mui and found contradictory results i.e. groups were more self-regarding.

[8] These two hypotheses are in opposition to the Social Comparison Theory by Cason and Mui (1997). This theory suggests that people are motivated to present themselves to the group in a socially desirable way. This may push the behavior of the group toward more other regarding behavior. We will address this theory more in the conclusion as it realtes to out results.

In the context of a Stackelberg game, behaving more competitively corresponds to players behaving in a more self-interested[9] manner. In particular, "social support of self-interested competitiveness" suggested the following hypothesis I:

Hypothesis I The "group" second movers are more likely to choose a best response that maximizes material payoffs than their "individual" counterparts.

The "schema-based distrust" hypothesis suggested that the following hypothesis II:

Hypothesis II The "group" first movers are more likely to believe that the second movers will act in a self-interested way, and best responds in a self-interested way as well than their "individual" counterparts .

2.2 Cooling-off

Classical economics assumes that agents are calm, flawless executors, and self-interested decision makers. However, a growing body of behavior economics research suggested that psychological and emotional factors can influence decision makers. One such emotional response is reciprocity, which can be either positive or negative. The experimental evidence suggested that subjects often reward "kind" actions by others with "kind" actions and punish "unkind" actions of others with "unkind" actions. In addition to the numerous lab experiments, Sanfey et al. (2003) provided neuroeconomic evidence supporting the importance of emotions in decision-making. In their study, subjects played an ultimatum game while undergoing fMRI brain scanning and they found that negative emotions, anger in particular, is associated to subjects' behaviors of rejecting offers that are deemed unfair. The authors recognized that "cooling-off periods" are one of the most employed and successful method to lessen angry moods. This is consistent with the dual-system models (see Kahneman (2003)) that portrays human behavior as an interaction between a hot system that responds to emotions and a cold system that responds to reasons. Zajonc (1984) shows that the emotional system tends to respond first. In a recent paper by Oechssler, Roider, and Schmitz (2008), the authors experimentally investigate how "cooling-off" affects rejection rates in an ultimatum game. They find that after a 24-hour period, a significant number of subjects who had initially rejected and unfair offer switch and accept the offer. Grimm and Mengel (2011) also find that a 10-minute cooling-off period reduces rejection rates by about 1/2 in an ultimatum game, from 80% in standard treatments to around 40-60% with a cooling-off period.

[9] We use the words "self-interested", "rational", "profit-maximizing" interchangably.

2.2.1 Research Hypotheses

In the context of the Stackelberg model, the SPE predicts that the first mover will exploit his/her advantage and choose a high quantity level ($q_a = 12$ in the model we consider). Second movers, motivated by maximizing profits, will then respond by choosing a relatively lower quantity ($q_b = 6$ in the model we consider). However, the results from HMN (2001) and HW (2002) suggest that second movers are motivated to negatively respond to this "unkind" action by first movers of choosing a high output quantity. In addition, second movers respond positively (do not exploit the first mover) to "kind" action of lower quantities chosen by the first mover. If cooling-off periods are effective at weakening the effect of emotions in decision-making, or, in Kahneman's terms, enables decision-maker to switch to the cold system, this would suggest that Stackelberg followers, after a cooling-off period, would adhere closer to the theoretical best response function. This leads to the following hypothesis III:

Hypothesis III The "cooled-off" second mover are more likely to choose a best response that maximizes material payoffs than their "hot" counterparts.

3 Experimental Design

3.1 The Model

Our design features a symmetric, exogenous timing, Stackelberg duopoly. There are two quantity setting firms, Firm A and Firm B. Let q_a and q_b denote their quantity choices respectively, and $Q = q_a + q_b$ be the total market output. The market price is given by the inverse demand function:

$$P(Q) = \max\{30 - Q, 0\} \text{ where } Q = q_a + q_b$$

and the linear cost functions are given by:

$$C_i(q_i) = 6q_i, i = a, b$$

The firms choose their quantities sequentially. First, the Stackelberg leader, A-firm, decides on its quantity q_a then, after observing q_a, the Stackelberg follower, B-firm, chooses its quantity q_b.[10] The subgame perfect equilibrium is ($q_a = 12$,$q_b(q_a) = 12 - q_a/2$). Thus, the Stackelberg equilibrium outcome (SE) is $q_a = 12$ and $q_b = 6$ yielding equilibrium profits of $\pi_a = 72$ and $\pi_b = 36$. The Cournot equilibrium outcome (CE) is $q_a = q_b = 8$ yielding profits of $\pi_a = \pi_b = 64$, and the joint profit maximizing outcome (JPM) is $q_a = q_b = 6$ yielding profits of $\pi_a = \pi_b = 72$.

We consider a discretized action set of the above Stackelberg game with nine possible quantity choices $q_i \in \{5, 6, 7, 8, 9, 10, 11, 12, 13\}$ for $i = a, b$. This action

[10]The model is similar to the one used by HMN (2001).

space allows the possibility of the Stackelberg, Cournot, and joint profit maximizing outcomes. Table 1 below displays the corresponding payoff matrix. Note, the discretized action space induces multiple equilibria in this Stackelberg game. To ensure uniqueness of the Stackelberg equilibrium and the Cournot equilibrium, we employ the same method as HNM (2001) and manipulate the payoff table slightly by subtract one from 10 of the 162 entries. For the experiment, the payoffs depicted in Table 1 were converted into dollars at a rate of 10:1.

		Firm B (Second Mover)								
		5	6	7	8	9	10	11	12	13
	5	70,70	65,78	60,84	55,88	50,89	45,90	40,88	35,84	29,78
	6	78,65	72,72	66,77	60,80	54,81	48,80	41,77	36,72	30,65
	7	84,60	77,66	70,70	63,72	55,71	49,70	42,66	35,60	28,52
Firm A	8	88,55	80,60	72,63	64,64	56,63	48,60	40,55	32,48	24,39
(First Mover)	9	89,50	81,54	71,55	63,56	54,54	45,50	36,44	27,36	18,26
	10	90,45	80,48	70,49	60,48	50,45	40,40	30,33	20,24	10,13
	11	88,40	77,41	66,42	55,40	44,36	33,30	22,22	11,12	0,0
	12	84,35	72,36	60,35	48,32	36,27	24,20	12,11	0,0	-12,-13
	13	78,29	65,30	52,28	39,24	26,18	13,10	0,0	-13,-12	-26,-26

Table 1: Payoff Table

3.2 Experimental Treatments

We conducted three treatments: (1) baseline, (2) group, and (3) cooling-off. Each experimental session involved only one of the three conditions. Each subject participated in only one treatment, thus we will implement a "between-groups" design. The three treatments are as follows.

Baseline (B) The baseline treatment involves subjects playing the discretized Stackelberg game once in either the role of Firm A or Firm B. The baseline treatment establishs a baseline measure of the departures from equilibrium under a standard lab environment.

Group (G) Here we used the same setup and procedure as Treatment B, but, the decision-making units consisted of 2-person groups. Each 2-person group is responsible to make one quantity decision for the group. No explicit instructions or rules were provided to govern how the group made its decision.

Cooling-off (C) Here we used the same setup and procedure as Treatment B except that subjects playing the role of Firm B were provided a 10-minute cooling-off period before making their decisions.

A simple questionnaire of approximately 10 minutes is administered in all treatments to all subjects. In the cooling-off treatment, the questionnaire takes place after Firm A's decision is revealed to Firm B, and before Firm B responded, thereby serving as the cooling-off period. In baseline and group treatments, the questionnaire takes place after Firm B's decision. As a result, subjects in all treatments spent approximately the same amount of time in the experiments. In all treatments, the subjects were informed in the instructions that they would be required to complete a questionnaire.

3.3 Experimental Procedure

All experimental sessions were conducted in the Economic Science Laboratory (ESL) at the University of Arizona. The subjects were undergraduates recruited via an online database. All sessions were programmed using z-Tree (Fischbacher 2007).[11] In total, 192 subjects participated, 50 in the baseline treatment (25 markets), 92 in the group treatment (23 markets) and 50 in the cooling-off treatment (25 markets). In addition to their experimental earnings, subjects received a $3 show-up payment [12]for participating. The average experimental earnings per subject, including the $3 show-up payment, was $9.49. Subjects were paid in private.

Upon entering the lab, subjects were seated at individual carrels to prevent communication, except in the Treatment G where subjects were allowed to communicate with their decision making partner. Subjects were randomly assigned either the role of first mover given a copy of the player's instruction, which were read aloud by the experimenter (A copy of the player's instructions can be found in the Appendix). Subjects were also given the payoff matrix and made aware of the 10:1 conversion rate into dollars. After reading the instructions, subjects were given 2 minutes to familiarize themselves with the payoff matrix. Before the decision task began, subjects were required to answer 2 questions about the payoff matrix to ensure their understanding of it.

The framing of the decision task was in line with HMN (2001). Namely, participants were told that they were to act as a firm which, together with another firm, produces a homogeneous product to serve the market demand. Their output decision, along with the output decision of their rival firm, would determine the profits to each firm. The primary agenda of our paper is to test the Stackelberg model in an environment more consistent with that of real firms. Therefore, it was appropriate to include firm specific framing as part of the experimental design, in lieu of a more "sanitized" setting with abstract framing.

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[11]We are grateful to Urs Fischbacher for providing the software for these experiments.

[12]We acknowledged that $3 show-up payment was lower than usual, but we believed it was appropriate as our experiment was quite short, with subjects getting in and out in less than 25 minutes.

3.4 Research Hypotheses

3.4.1 Group Decision-making

Both the "social support of self-interested competitiveness" hypothesis and the "schema-based distrust" hypothesis suggested more competitive behavior by group decision makers compared to individual decision makers. In the context of the Stackelberg game, more competitive behavior manifests itself in the form of more rational decision making. Recall, HMN (2001) found that the Stackelberg followers' reaction functions are less steep than predicted. This is consistent with both inequality aversion and reciprocity by the second mover. If individuals as Stackelberg followers are motivated by pressure from preference to equality, then the "social support of self-interested competitiveness" hypothesis would suggest that groups as Stackelberg followers to adhere more closely to the best response function. This leads to the following testable hypothesis for second mover behavior:

Hypothesis 1: The proportion of Firm Bs choosing the best response output quantity is higher in Treatment G compared to Treatment B.

The "schema-based distrust" hypothesis suggested that we will see more rational decision making in Treatment G compared to Treatment B. This leads us to the following testable hypothesis for first mover behavior:

Hypothesis 2: The proportion of Firm As choosing $q_a = 12$ is higher in Treatment G than in Treatment B.

3.4.2 Cooling-off

If cooling-off periods work to lessen or weaken the effect of emotions in decision-making, then Stackelberg followers should adhere more closely to the best response function. This leads to the following hypothesis regarding second mover behavior:

Hypothesis 3: The proportion of Firm Bs choosing the best response output quantity is higher in Treatment C than in Treatment B.

4 Results

We begin by looking at the breakdown of market outcomes across the three treatment. We classify the outcomes into the following 4 categories: Stackelberg Equilibrium (SE) where $q_a = 12$ and $q_b = 6$, Cournot Equilibrium (CE) where $q_a = 8$ and $q_b = 8$, the Joint Profit Maximizing Outcome (JPM) where $q_a = 6$ and $q_b = 6$, and other. Table 2 presents the market outcome results across the three treatments.

Outcome	Treatment B	Treatment G	Treatment C
SE	1	0	1
CE	2	3	2
JPM	0	2	0
Other	22	18	22
Total	25	23	25

Notes: Outcomes were tested using a Fisher's Exact test

Table 2: Market Outcomes – All Treatments

From Table 2, we can see that of the 73 total markets, there were 2 SE outcomes, 7 CE outcomes, 3 JPM outcomes, and 61 other outcomes. It is clear from Table 2, that the data is inconsistent with the theoretically predicted Stackelberg Equilibrium, regardless of the treatment. However, deviations from the Stackelberg Equilibrium outcome result if either the first mover fails to produce $q_a = 12$, or the second mover fails to best respond. We proceed by investigating the behavior of first movers and second movers across the three treatments.

The theoretical prediction of the Stackelberg game is that second movers will choose the quantity that maximizes profits, i.e. second movers will best respond. Table 3 presents the aggregate second mover data for each treatment. The second mover data is broken down into three categories. *Panel A* displays the unconditional second mover data for all markets. *Panel B* displays only the data for second movers who's corresponding first mover chose $q_a \leq 8$. *Panel C* displays only the data for second movers who's corresponding first mover chose $q_a > 8$. We define the measure % of BR profits as the percentage of the best response profits (the maximum amount) the second mover earned from their actual output choice.

From Table 4 (*Panel A*), we can see that across all treatment only 32/73 (44%) of second movers best responded, and earned 90% of the BR profits. Across all treatment, when the first movers choose $q_a \leq 8$ (*Panel B*), 16/32 (50%) of second movers best responded and earned 96% of BR profits. Across all treatments, when the first movers chose $q_a > 8$ (*Panel C*), 15/40 (38%) of second movers best responded and earned 85% of BR profits. Overall, the behavior of second movers appears to be inconsistent with the theoretical prediction of choosing the best response, regardless of treatment.

Recall our Hypothesis 1, was that the proportion of second movers who best respond is higher in Treatment G compared to Treatment B. From Table 3, we can see that there are no significant differences in the proportion of second movers who best respond, or the % of BR profits earned between Treatment G and Treatment B.

This holds for all q_a, when $q_a \leq 8$, and when $q_a > 8$. Thus we cannot find support for Hypothesis 1.

Table 3: Second Movers (SM) Response Data – All Treatments

	Treatment B	Treatment G	Treatment C
Panel A: Unconditional			
	Treatment B	Treatment G	Treatment C
Prop playing a BR	12/25 (48%)	10/23 (43%)	10/25 (40%)
Abs deviation from BR	1.16	1.30	1.80
% of BR profits	91%	92%	87%
Panel B: Conditional on $q_a \leq 8$			
	Treatment B	Treatment G	Treatment C
Prop playing a BR	4/8 (50%)	7/15 (47%)	5/9 (56%)
Abs deviation from BR	0.86	1.10	1.00
% of BR profits	97%	96%	97%
Panel C: Conditional on $q_a > 8$			
	Treatment B	Treatment G	Treatment C
Prop playing a BR	7/16 (43%)	3/8 (38%)	5/16 (31%)
Abs deviation from BR	1.36	1.75	2.25
% of BR Profits	88%	87%	82%

Notes: The average output was tested using a Mann-Whitney test and the proportions were tested using a Fisher's Exact test. All tests were in relation to Treatment B.

Our third hypothesis, Hypothesis 3, was that the proportion of second movers who best respond is higher in Treatment C compared to Treatment B. Table 3 reveals that there are no significant differences in the proportion of second movers who best respond, of the % of BR profits earned between Treatment G and Treatment B for all levels of q_a. If anything, these is marginal evidence that second mover on Treatment C are less likely to best respond. Thus, we cannot find support for Hypothesis 3.

	Treatment B	Treatment G	Treatment C
Average Output – q_a	9.88	8.13***	9.04
Prop choosing $q_a = 12$	6/25 (24%)	1/23 (04%)*	1/25 (04%)
Prop choosing $q_a = 8$	5/25 (20%)	5/23 (22%)	4/25 (16%)
Prop choosing $q_a = 6$	2/25 (08%)	5/23 (22%)	0/25 (00%)

Notes: The average output was tested using a Mann-Whitney test and the proportions were tested using a Fisher's Exact test. All tests were in relation to Treatment B.
* significance at the 10% level ** significance at the 5% level

Table 4: First Movers (FM) Output Data – All Treatments

Table 4 presents the aggregate output data for first movers across treatments. We can see that in all treatments, the average first mover output quantity is lower than the Stackelberg Equilibrium quantity of 12. In aggregate, only 8/73 (11%) of first movers chose $q_a = 12$. In general, the data suggests that first movers do not attempt to exploit their first mover advantage, regardless of the treatment.

Recall our Hypothesis 1, was that first movers from Treatment G choose $q_a = 12$ more than first movers from treatment B. Table 4 reveals that 6/25 (24%) first movers from Treatment B chose $q_a = 12$ compared to 1/23 (4%) in Treatment G. Therefore we cannot find support for Hypothesis 2. In fact, Fisher's Exact test revealed that a significantly higher proportion of first movers choosing $q_a = 12$ in Treatment B compared to Treatment G (p = 0.062). Additionally, the mean first mover output of 9.88 in Treatment B is significantly higher than the mean output of 8.13 in Treatment G using a Mann-Whitney test (p = 0.005). Taken together, the data suggests that groups acting as first movers choose that equilibrium quantity less frequently, and choose relatively lower output levels compared to the individuals acting as first movers.

To provide a "bird's-eye" view of the general behavioral tendencies, we also regroup the output levels into the following broader categories: low output (L) if $q_i \in \{5, 6, 7\}$, medium output (M) if $q_i \in \{8, 9\}$, and high output (H) if $q_i \in \{10, 11, 12, 13\}$. Analogously, we classify approximate outcomes into the following 4 categories: approximate Stackelberg Equilibrium ($\widehat{\text{SE}}$) as (H,L), approximate Cournot Equilibrium ($\widehat{\text{CE}}$) as (M,M), the approximate joint profit maximizing outcome ($\widehat{\text{JPM}}$) as (L,L), and other. Table 5 presents the relevant data by treatment.

Outcome	Treatment B	Treatment G	Treatment C
$\widehat{\text{SE}}$	9	2**	4
$\widehat{\text{CE}}$	3	4	5
$\widehat{\text{JPM}}$	0	5**	0
Other	13	12	16
Total	25	23	25

Notes: Outcomes were tested using a Fisher's Exact test. All tests were in relation to Treatment B.
*** Significance at the 1% level

Table 5: Approximate Market Output – All Treatments

Under the broader categorization of the market outcomes, Table 4 shows that aggregates over all treatments only 15/73 (21%) of markets achieve the $\widehat{\text{SE}}$ outcome. However, there are significantly more $\widehat{\text{SE}}$ outcomes in Treatment B compared to Treatment G (p = 0.026). Additionally, there are significantly more $\widehat{\text{JPM}}$ outcomes in Treatment G compared to Treatment B (p = 0.020). This reinforces that the idea that groups appear to be behaving more cooperatively and less in line with theoretical predictions compared to the baseline.

	Treatment B	Treatment G	Treatment C
Prop choosing H	16/25 (64%)	7/23 (30%)**	13/25 (52%)
Prop choosing M	6/25 (36%)	6/23 (26%)	7/25 (28%)
Prop choosing L	3/25 (12%)	10/23 (44%)**	5/25 (20%)

Notes: Proportions were tested using a Fisher's Exact test. All were in relation to Treatment B.
** Significance at the 5% level

Table 6: Approximate First Movers (FM) Output Data – All Treatments

Table 6 shows the proportion of FM choosing L, M, and H for each Treatment. From Table 6, we can see that significantly more first movers in Treatment B choose H compared to Treatment G (p = 0.020). Additionally, significantly more first movers in Treatment G choose L compared to Treatment B (p = 0.016). This suggest that groups acting as first movers exhibit more cooperative behavior that individuals acting as first movers.

5 Conclusion

The previous experimental tests of the Stackelberg duopoly model have found little support of the theoretical predictions of the model (HNM (2001) and HW (2002)). We hypothesize that the theoretically inconsistent results from HNM (2001) and HW (2002) are a result of systematic difference between lab environment and naturally occurring firm environments. These environmental differences may limit the generalizability of the lab results to firms in the field. The motivation of the study is twofold. The first is to experimentally investigate how group decision making units influences behavior of first and second movers compared to individuals in an experimental Stackelberg game. Specifically, do groups behave more rationally than individuals. Second, this study experimentally investigates whether a cooling-off period in effective at mitigating the emotional influence of second mover decisions in a Stackelberg game. We argue that group decision making units and cooling-off periods are both indicative of decision making units in the field, hence our motivation to investigate their impact on decision making in an experimental Stackelberg duopoly in the lab.

In line with HMN (2001), our aggregate experimental data is inconsistent with the theoretical predictions of the Stackelberg model. In particular, across all treatments, only 2/73 (3%) markets resulted in the Stackelberg Equilibrium outcome. This is predominately driven by first movers choosing lower than predicted output levels i.e. their failure to exploit their first mover advantage. In terms of the treatment effects, we first find that groups acting as first movers choose significantly lower output levels compared to individual first movers, which is counter to our first hypothesis. We find little difference in the response behavior between groups acting as second movers compared to individual second movers. In terms of the cooling-off period, we again find little difference in response behavior of second movers who had a 10 minute cooling-off period and those who did not. The differences that do exist, although not significant, indicate that second movers who cool-off may be more influenced by emotions, which is counter to our third research hypothesis that a cooling-off period would help mitigate emotional influences.

How can these counter hypothesized results be reconciled? It appears that groups acting as first movers appear to exhibit more cooperative behavior compared to individuals. There are two plausible explanations. The first, is in line with what Cason and Mui (1997) refer to as Social Comparison Theory (SCT). SCT suggests that people are motivated to present themselves to the group in a socially desirable way.

In a Stackelberg game, exploiting ones first mover advantage may not be thought of as “socially desirable”. This may lead group first movers to choose lower, more co-operative levels of output. The second, is that the group second movers collectively believe that second movers will “punish” them for trying to exploit their first mover advantage. That is, groups rationally choose lower levels of output because they anticipate negative reciprocity by the second mover. Without data on the first-order beliefs of first movers it is impossible for us to distinguish between the former and the latter. Although we are inclined to speculate that SCT is the driving force.

The data also reveals that the cooling-off period is ineffective at mitigating emotional influences of second movers. If anything, there is marginal evidence to suggest that the cooling-off period amplified the emotional influence of second movers; in the sense that the cooling-off period appears to have amplified second movers motivation to reciprocate, both positively and negatively. The alleged “cooling-off” period may have actually acted as “heating-up” period for harboring and manifesting emotions. We acknowledge that this may be a by-product of the length of the cooling-off period, 10 minutes. This may call to question the robustness with regards to longer cooling-off periods. However, to our knowledge the literature related on cooling-off periods does not postulate any formal model liking the length and effectiveness of the cooling-off period. Additionally, Grimm and Mengel (2011) found evidence that a 10 minute cooling-off period was effective. This suggests that there may be something inherent to the Stackelberg game, and not the length of time, that amplifies emotional influence in a Stackelberg game.

The previous experimental studies related to groups decision making and cooling-off periods generally finds: (1) groups exhibit more rational decision making (cf. Cason and Mui (1997)), and (2) cooling-off periods mitigate the influence of emotions which leads to more rational decision making. Our results suggest that in the context of a Stackelberg duopoly, groups exhibit less rational decision making, and cooling-off periods amplify the emotional influence on decision making. We posit that out results should be viewed as complementary, and not as contradictory, to the previous literature. In the sense that we find different results, but we also consider a different game from those previously studied. Future research that investigates under what conditions of a strategic settings lead groups to make more rational decisions, and cooling-off periods to be effective is warranted.

6 Appendix

6.1 Player Instructions - Baseline Treatment

PLAYER INSTRUCTIONS

Welcome to our experiments! Please read these instructions carefully! Do not talk to your neighbors and please remain quiet during the entire experiment. Raise your hand if you have a question. We will answer them privately.

In our experiment, you can earn different amounts of money, depending on your decisions and the decision of the other participants who are matched with you.

You play the role of a firm which produces the same product as another firm in the market. Both firms always have to make a single decision, namely the amount of output they want to produce in this market. The profit to each firm will depend on the level of output chosen by each of the firms. In the table on the other sheet that is given to you, you can see the profits of each firm for all possible output combinations of the two firms.

The table reads as follows: the header of the row represents one firm's output decision (Firm-A) and the header of the column represents the output decision of the other firm (Firm-B). Inside the little box where row and column intersect, Firm-A's profit corresponding to this combination of outputs is the number to the left. Firm-B's profit corresponding to this combination of outputs is the number to the right. The profit is denoted in a fictitious unit of money which we call Taler. Before the experiment begins, you will have a few minutes to look over the payoff table. You will then be asked two control questions about the matrix to ensure your understanding of it.

You have been randomly assigned either the role of Firm-A or Firm-B, and randomly matched to another participant of the opposite role. After the two control questions, your Firm role will be revealed to you. The experiment will proceed in three stages.

Stage 1:

Firm-A will begin by choosing an output level to produce. Firm-A's output level will then be revealed to Firm-B.

Stage 2:

Firm-B will then respond by choosing an output level to produce.

Stage 3:

The output decisions of both Firms and the corresponding profits of each Firm will be displayed to both Firms. You will then be asked to complete a simple questionnaire that will take approximately 10 minutes to complete.

After all three stages are complete; you will be privately paid your experimental earnings. Your profit in Talers from the decision task will be converted to $

at a rate of 10-1. That is, every 10 Talers correspond to $1 USD. In addition to your profit, you will receive a $3 USD show-up payment for participating in the experiment. All decisions and answers to the questionnaire will be kept anonymous among the participants and the experimenters.

6.2 Player Instructions - Cooling-off Treatment

PLAYER INSTRUCTIONS

Welcome to our experiments! Please read these instructions carefully! Do not talk to your neighbors and please remain quiet during the entire experiment. Raise your hand if you have a question. We will answer them privately.

In our experiment, you can earn different amounts of money, depending on your decisions and the decision of the other participants who are matched with you.

You play the role of a firm which produces the same product as another firm in the market. Both firms always have to make a single decision, namely the amount of output they want to produce in this market. The profit to each firm will depend on the level of output chosen by each of the firms. In the table on the other sheet that is given to you, you can see the profits of each firm for all possible output combinations of the two firms.

The table reads as follows: the header of the row represents one firm's output decision (Firm-A) and the header of the column represents the output decision of the other firm (Firm-B). Inside the little box where row and column intersect, Firm-A's profit corresponding to this combination of outputs is the number to the left. Firm-B's profit corresponding to this combination of outputs is the number to the right. The profit is denoted in a fictitious unit of money which we call Taler. Before the experiment begins, you will have a few minutes to look over the payoff table. You will then be asked two control questions about the matrix to ensure your understanding of it.

You have been randomly assigned either the role of Firm-A or Firm-B, and randomly matched to another participant of the opposite role. After the two control questions, your Firm role will be revealed to you. The experiment will proceed in three stages.

Stage 1:

Firm-A will begin by choosing an output level to produce. Firm-A's output level will then be revealed to Firm-B.

Stage 2:

Both Firms will then be asked to complete a simple questionnaire that will take approximately 10 minutes to complete.

Stage 3:

After the questionnaire, Firm-B will then respond by choosing an output level to produce.

Then output decisions of both Firms and the corresponding profits of each Firm will be displayed to both Firms.

After all three stages are complete; you will be privately paid your experimental earnings. Your profit in Talers from the decision task will be converted to \$ at a rate of 10-1. That is, every 10 Talers correspond to \$1 USD. In addition to your profit, you will receive a $3 USD show-up payment for participating in the experiment. All decisions and answers to the questionnaire will be kept anonymous among the participants and the experimenters.

6.3 Player Instructions - Group Treatment

PLAYER INSTRUCTIONS

Welcome to our experiments! Please read these instructions carefully! You are only allowed to talk with your partner, the person who is sharing your carrel. Please do not talk with your neighbors. Raise your hand if you have a question. We will answer them privately.

In our experiment, each group can earn different amounts of money, depending on your group's decision and the decisions of the other groups who are matched with your group. However, within a group, all group members will earn the amount of money the group earns.

You and your partner comprise a group that plays the role of a firm which produces the same product as another firm in the market. Both firms always have to make a single decision, namely the amount of output they want to produce in this market. The profit to each firm will depend on the level of output chosen by each of the firms. In the table on the other sheet that is given to you, you can see the profits of each firm for all possible output combinations of the two firms.

The table reads as follows: the header of the row represents one firm's output decision (Firm-A) and the header of the column represents the output decision of the other firm (Firm-B). Inside the little box where row and column intersect, Firm-A's profit corresponding to this combination of outputs is the number to the left. Firm-B's profit corresponding to this combination of outputs is the number to the right. The profit is denoted in a fictitious unit of money which we call Taler. Remember, within a group, each group member will earn the same amount of profit as the Firm. Before the experiment begins, each Firm will have a few minutes to look over the payoff table. Each Firm will then be asked two control questions about the matrix to ensure your understanding of it.

You and your partner have been randomly assigned either the role of Firm-A or Firm-B, and randomly matched to another group of the opposite role. After the two control questions, your Firm role will be revealed to you. The experiment will proceed in three stages.

Stage 1:

Firm-A will begin by choosing an output level to produce. Firm-A's output level will then be revealed to Firm-B.

Stage 2:

Firm-B will then respond by choosing an output level to produce.

Stage 3:

The output decisions of both Firms and the corresponding profits of each Firm will be displayed to both Firms. You will then be asked to complete a simple questionnaire that will take approximately 10 minutes to complete. One person in the group will move to the empty carrel to your right to complete their own questionnaire.

After all three stages are complete; each person will be privately paid your experimental earnings. Your profit in Talers from the decision task will be converted to $ at a rate of 10-1. That is, every 10 Talers correspond to $1 USD. In addition to your profit, you will receive a $3 USD show-up payment for participating in the experiment. All decisions and answers to the questionnaire will be kept anonymous among the other participants and the experimenters.

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