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Do hormones impact behavior in the minimum effort game? - An experimental investigation of human behavior during the weakest link game after the administration of vasopressin -

Stephan Schosser/Bodo Vogt

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Stephan Schosser/Bodo Vogt
Otto-von-Guericke-Universität Magdeburg
Fakultät für Wirtschaftswissenschaft
Postfach 4120
39016 Magdeburg
Germany

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Do hormones impact behavior in the minimum effort game?

- An experimental investigation of human behavior during the weakest link game after the administration of vasopressin -

Stephan Schosser[a*], Bodo Vogt[a]

[a]*Universtity of Magdeburg, Universtitätsplatz 2, 39106 Magdeburg, Germany*

[*]*Corresponding author*

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Abstract

This paper describes an experimental study involving the minimum effort game. In this game, each player faces a trade-off between risk and payoff. Within each group, half of the subjects were administered with vasopressin in nasal spray form while half received a placebo. We found that subjects who received vasopressin were more likely to play the minimally risky strategy in the group and less likely to focus on payoff levels than those who received the placebo.

Keywords

minimum effort game; coordination game; neuroeconomic experiment; vasopressin

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1 Introduction

When analyzing cooperation and coordination, we often find what is commonly referred to as *subject effects*; i.e., effects that only occur in certain laboratories or geographic regions (Hermann et al., 2008; Henrich et al., 2001; Engelmann & Normann, 2010). Aside from the more obvious explanations for subject effects, namely cultural or genetic differences, several results have one fact in common:

subject effects often occur between southern and northern regions of the world. That is, the behavior of individuals who are based in countries that are bathed in enduring sunshine seems to deviate from that of individuals who are based in countries with short days. This observation is interesting from a neuro-economic perspective, and various studies have shown that the dissemination of hormones is driven by the amount of sun we encounter (Reppert et al., 1981; Windle et al., 1992; Young, 2007). In order to better understand human behavior, therefore, we need to develop a deeper understanding of hormone-controlled motives. This paper describes an experiment that examined the impact that vasopressin, a neurohypophysial hormone, has on human behavior in the context of a coordination problem; namely, the minimum effort game. It is envisaged that the results of this research will enhance existing understanding of equilibrium selecton in coordination games.

In the minimum effort game, which is also known as the weakest link game (Van Huyck et al., 1990), every player from a group of several players chooses his effort level. The effort level selected influences the potential payoffs of both, the group to which the player belongs and the player himself. On the one hand, the player faces costs and these increase according to the level of his effort; on the other hand, the payoff increases in accordance with the minimum effort in the group. In equilibrium, all players choose identical effort levels: choosing a higher effort level than the other group members only increases the costs of one player, not the minimum effort in the group. A lower effort level reduces the player's own costs, but also the minimum effort level of the group. As the cost reduction achieved by lowering one's effort lies below the benefit loss associated with decreasing the minimum effort, deviating from equilibrium by choosing a lower effort does not appeal. Similar to other coordination games, the minimum effort game offers a discrepancy between payoff maximization and risk minimization:

the lower the effort of a player, the lower his risk of being exploited by another group member choosing lower effort levels. However, the higher the individual effort, the higher the potential minimum and, therefore, the higher the potential payoff.

In laboratory experiments that observe human behavior during the minimum effort game, two outcomes typically occur (Van Huyck et al. 1990):

1. In small groups, all group members coordinate towards choosing the maximum effort level; i.e., play the payoff dominant equilibrium.
2. In larger groups (about six players), all group members chose the lowest possible effort level; i.e., coordinate towards the risk dominant equilibrium.

Most experimental studies have focused on the development of methods that ensure the payoff dominant equilibrium is played, even in larger groups. One popular approach involves increasing the information that is available about the effort levels of others. Initial work, such as that by Van Huyck et al. (1990) only communicated the minimum effort level in the group and the payoff of the player at the end of a period. However, later experiments also displayed the distribution of the individual effort levels in the group (Berninghaus & Ehrhart, 2001). In this way, even larger groups reach the payoff dominant equilibrium. However, the subjects need to be aware of the efforts of all other group members. If they are only aware of the effort levels of some of their peers, this does not result in the group playing the payoff dominant equilibrium (Deck & Nikiforakis, 2012). Another approach to promote the payoff dominant equilibrium in larger groups involves communicating the desired result. In an experiment in which the experimenter informed the participants that the desired result in the minimum effort game is to play the maximum effort, several large groups reached the payoff dominant equilibrium (Chaudhuri & Paichayontvijit, 2010). Finally, competition can help to ensure high effort levels in larger groups. First of all, research has shown that the elimination of the weakest group member does not motivate all others to choose higher effort levels (Fatas et al., 2006). What helps, is competition with other groups. Namely, by increasing the payoff of all players in a group if they chose the highest minimum effort in a set of groups, increases the effort levels of all players and the likelihood that the group will reach the payoff dominant equilibrium (Bornstein et al., 2002). Unfortunately, intergroup competition on the long run only works for the winning group. That is, groups who do not perform better than the other groups (at least in some periods) end up in the low effort levels in the absence of intergroup competition (Riechmann & Weimann, 2008).

Existing research also suggests that the cultural background of the subjects who are participating in the minimum effort game has a major impact on their behavior. Both the dissemination of individual effort levels and the communication of the desired result represent methods of identifying the "cultural norm"; that is, if all subjects in the population are aware of the norm their fellow group members will resort to, they will also follow this norm. Even the experiments on competition themselves can be perceived as a means of establishing a norm. By telling the members of a group they frequently have higher (lower) effort levels than the other groups, one implicitly communicates the norm of the group itself. All group members begin following the norm in their group by either lowering or increasing their effort levels. In this sense, it is not surprising that subject effects occur in the minimum effort game. For example, a minimum effort game conducted in Copenhagen, Denmark (Engelmann & Normann, 2010), revealed that the payoff dominant equilibrium was reached even in larger groups if enough Danish subjects participated. Compared to other countries - namely, the United States, Israel and Spain - effort levels in Denmark are higher.

The question arises, then, as to why the behavior of participants from Denmark differs from those from other countries and yields different experimental results in the minimum effort game.

This paper describes a neuro-economic experiment that was designed to gain insights into how culture can affect behavior during the minimum effort game. When the experiment on cultural differences between Danish and other students (Engelmann & Normann, 2010) was conducted in November and December 2006, the days were short in Copenhagen, and people were exposed to sunlight for just a few hours per day. This influences the hormonal balance of subjects; namely, their levels of vasopressin are lower at night and, when confronted with daylight, vasopressin levels increase (Reppert, 1981). In addition, research investigating the impact of hormones, such as vasopressin, shows that hormones influence even complex human behavior (e.g., Kosfeld et al., 2005; Meyer-Lindenberg et al., 2011). In particular, aggression is correlated with cerebrospinal fluid levels of vasopressin (Coccaro et al., 1998) and vasopressin increases reciprocity in the prisoners' dilemma games (Rilling et al., 2012). Hence, the differences between the behavior of Danish people and other subjects as they play the minimum effort game may be the result of lower hormone levels. These differences in hormone levels might also influence the cultural norms established.

We find that subjects who had been administered with vasopressin showed equal behavior during the first round of the minimum effort game as those who received a placebo. From that point forward, until the equilibrium was reached, subjects under vasopressin exhibited lower effort levels than those who received the placebo. These results are in line with the differences between Copenhagen and other experimental labs. As the subjects in Denmark were exposed to less daylight, their vasopressin levels were lower. Hence, based on our experiment, we expect them to show higher effort levels which, according to the experiments in Denmark (Engelmann & Normann, 2010), does occur.

We believe that this result has significant implications for economics. Existing literature supports the notion that cultural norms impact individual's behavior in minimum effort games. If hormones, on the other hand, justify the observed behavior, are our norms consequences of hormonal levels or culture?

2 Game

In the minimum effort game conducted for the purposes of this study, a group of $n = 4$ players participated. Each player $i \in I = \{1,..,n\}$ could choose his strategy; i.e., his effort, $\sigma_i \in \{1, 2, \dots, 7\}$. The payoff per player was $\pi_i(\sigma_i, \sigma_{-i}) = 30 + 10 \cdot \min_{\forall j \in I}(\sigma_j) - 5 \cdot \sigma_i$. That is, the payoff of each player i depended on the minimum effort any of the players chose and the payoff of player i. Table 1 summarizes the payoff table.

Table 1: Payoffs based on own effort and minimum effort of the group

		Minimum effort of group ($\min_{\forall j \in I}(\sigma_j)$)						
		1	*2*	*3*	*4*	*5*	*6*	*7*
Own effort (σ_i)	*1*	35	-	-	-	-	-	-
	2	30	40	-	-	-	-	-
	3	25	35	45	-	-	-	-
	4	20	30	40	50	-	-	-
	5	15	25	35	45	55	-	-
	6	10	20	30	40	50	60	-
	7	5	15	25	35	45	55	65

In equilibrium, all players i choose identical effort levels σ_i. One can easily see this in the payoff table (see Table 1). Let us, for example, assume that all players j choose an effort level $\sigma_j = 4$. Now, all players receive a payoff of 50. If player i chooses a higher effort level $\sigma_i > 4$, his payoff will decrease to 45 when setting $\sigma_i = 5$, 40 when setting $\sigma_i = 6$, and so on (see Column "4" in Table 1). That is, player i cannot increase his payoff by choosing a higher effort level than the other players. Similar observations hold if player i decreases his effort level to $\sigma_i < 4$. Now, the new minimum effort level is σ_i. The payoff decreases to 45 when choosing $\sigma_i = 3$, 40 when choosing $\sigma_i = 2$, and so on. That is, player i cannot increase his payoff by unilaterally deviating from playing the same strategy as all other players. In consequence, the minimum effort game has $|\sigma_i|$ different equilibria – one equilibrium for every possible effort level.

All equilibria form a natural order. On the one hand, every Nash equilibrium $(\sigma_i, \sigma_i, \sigma_i, \sigma_i)$ is a payoff superior to every other Nash equilibrium $(\sigma_j, \sigma_j, \sigma_j, \sigma_j)$ with $\sigma_j < \sigma_i$. One can easily see this by looking at the payoff table in Table 1. Let us again look at the Nash equilibrium $(4,4,4,4)$. All equilibria with effort levels below 4 yield lower payoffs for all players. However, every equilibrium with higher effort levels yields higher payoffs for all players. Similarly, the Nash equilibria form an order concerning risk: for all effort levels, the average payoff is 35 given that all minimum effort levels are equally likely. However, the higher the effort level σ_i, the higher the potential loss of player i if one of the other group members chooses an effort level of 1 (see Column "1" in Table 1). That is, the lower σ_i, the less risky the chosen strategy.

In sum, the minimum effort game offers a dilemma between payoff and risk dominance, as all 2x2-matrix coordination games do. If all subjects choose the minimum effort level, the overall payoff is minimal, while the risk of receiving a lower payoff is low. The higher the effort level played in equilibrium, i.e., the higher the payoff of the players, the higher the potential loss if one of the group members deviates. In contrast to bi-matrix coordination games, the minimum effort game allows for different equilibria and, therefore, different levels of payoffs and risk.

3 Material and methods

A total of 148 healthy males (aged 20 to 35) participated in this research. Upon arrival at the laboratory, each of the subjects was assigned to one of 37 groups of four people. Within each group, two subjects were treated with a placebo and two subjects were treated with vasopressin in the form of a nasal spray.

Prior to the experiment, all subjects signed a consent form. Once they had done so, they received a nasal spray that contained 40 international units of either a placebo or vasopressin. The subjects then completed several questionnaires, including an aggression questionnaire (Buss & Perry, 1992); a mood questionnaire (Steyer et al., 1997); and a questionnaire on risk preferences. They then read the instructions to the game. The experimenter answered any questions the participants had about the game and ensured that 30 minutes since drug administration had passed before the game commenced. This ensured that the vasopressin levels in those subjects who had been administered vasopressin reached peak levels in the cerebrospinal fluid (Born et al., 2002).

All groups played the minimum effort game as described in Section 2. The game was iterated for 10 periods (computerized using zTree; Fischbacher, 2007). At the end of each period, all subjects were informed of the minimum effort chosen in their group. When the subjects had finished playing the minimum effort game, they filled out the same questionnaires they had completed prior to the game, and then completed a fairness task. In the fairness task, the subjects were asked to choose one of five different allocations, with one allocation being a 50:50 allocation between the subject and another random subject in the room, and all other allocations differing from this allocation by favoring the deciding player to another extent.

After the subjects had finished all tasks, they were paid according to their performance in the minimum effort game. That is, each subject received 0.035 SFR per point received as well as a show-up fee of 10.00 SFR. In addition, the fairness task was implemented for one random subject in the room. The average payoff per player was 30.46 SFR (minimum: 17.67 SFR, maximum: 43.75 SFR). On average, the experiments lasted one hour and 30 minutes.

4 Results

Figure 1 illustrates the impact of vasopressin on the effort level subjects chose throughout the game. While effort levels did not differ between the subjects per group who received a placebo and the subjects who received vasopressin in the first period (Wilcoxon test, two-sided; means: p=0.193; minima: p=0.302), subjects treated with vasopressin gave significantly less in periods 2 (Wilcoxon test, two-sided; means: p=0.005; minima: p=0.008), 4 (Wilcoxon test, two-sided; means: p=0.014; minima: p=0.022) and 5 (Wilcoxon test, two-sided; means: p=0.030; minima: p=0.094). Starting in period 6, the subjects reached an equilibrium. After this period, no differences between the subjects was observed (Wilcoxon test, two-sided; means: p=0.674 (t=6), p=0.858 (t=7), p=0.300 (t=8), p=0.351 (t=9), p=0.332 (t=10); minima: p=0.904 (t=6), p=0.887 (t=7), p=0.861 (t=8), p=1.000 (t=9), p=0.258 (t=10)). As such, on average, the mean effort levels selected over the course of ten periods of the weakest link game differed according to whether the participant had been administered a placebo or vasopressin (Wilcoxon test, two-sided, p=0.006).

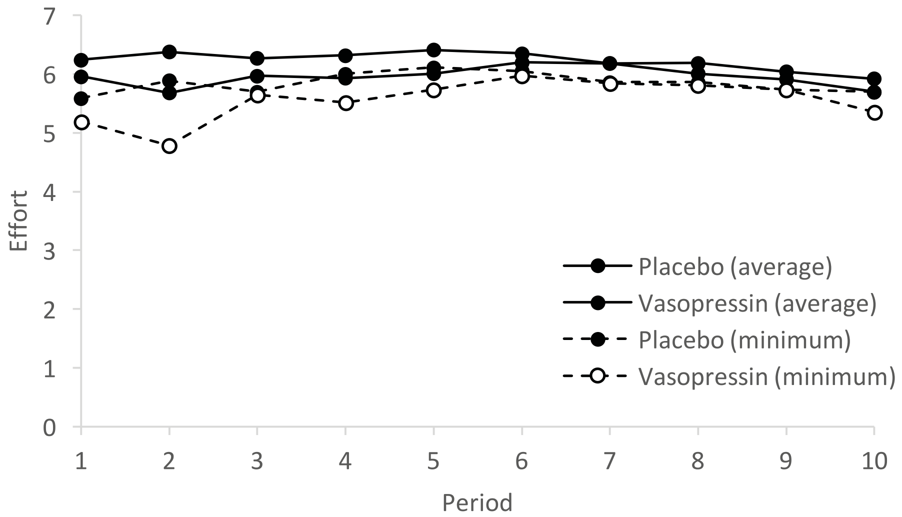

Figure 1: Average and minimum effort per group and period

The differences in the effort levels between the subjects who received a placebo and those who received vasopressin also resulted in differences in the payoffs (see Table 2). In terms of effort levels, the subjects who were administered vasopressin achieved significantly higher payoffs for periods 2, 3, 4 and 5 (Wilcoxon test, two-sided; means: p=0.005 (t=2), p=0.014 (t=4), p=0.030 (t=5)), while no difference in payoffs was observed during the other periods (Wilcoxon test, two-sided: p=0.193 (t=1), p=0.203 (t=3), p=0.674 (t=6), p=0.858 (t=7), p=0.300 (t=8), p=0.351 (t=9), p=0.332 (t=10). Overall, payoffs were higher for the subjects who received vasopressin than for those who received the placebo (Wilcoxon test, two-sided: p=0.006).

Table 2: Payoffs per group over all periods. Values in brackets indicate extent of differences between Placebo and Vasopressin players (positive: payoff vasopressin > payoff placebo)

Grp.	Payoff	(Diff.)	Grp.	Payoff	(Diff.)	Grp.	Payoff	(Diff.)
1	44.0	(4.5)	*14*	53.4	(0.0)	*27*	36.9	(-5.8)
2	54.5	(3.0)	*15*	45.3	(2.3)	*28*	52.5	(2.5)
3	41.0	(2.5)	*16*	50.6	(2.5)	*29*	53.0	(2.5)
4	65.0	(0.0)	*17*	49.9	(-9.0)	*30*	53.5	(2.0)
5	65.0	(0.0)	*18*	61.3	(2.5)	*31*	55.4	(4.3)
6	64.1	(0.3)	*19*	61.5	(0.0)	*32*	41.3	(5.0)
7	55.8	(-1.0)	*20*	54.0	(-1.0)	*33*	53.4	(0.3)
8	48.0	(-3.0)	*21*	53.3	(0.5)	*34*	53.1	(3.8)
9	54.5	(0.0)	*22*	55.3	(2.5)	*35*	64.1	(-0.3)
10	43.0	(2.5)	*23*	53.4	(0.0)	*36*	21.9	(15.8)
11	60.8	(1.0)	*24*	61.6	(-0.5)	*37*	55.5	(1.5)
12	*30.8*	*(6.0)*	*25*	*32.9*	*(1.0)*			
13	65.0	(0.0)	*26*	60.9	(2.8)	*Avg.*	52.2	(1.4)

Analysis of the differences between individual effort levels and the minimum effort level of the group indicated that the relative frequencies of these differences tended to be different between placebo and vasopressin subjects (Chi-squared test, two-sided, p=0.082). In sum, the subjects who received vasopressin significantly more frequently chose the minimum in the groups than the subjects who received the placebo (Wilcoxon test, two-sided, p=0.027).

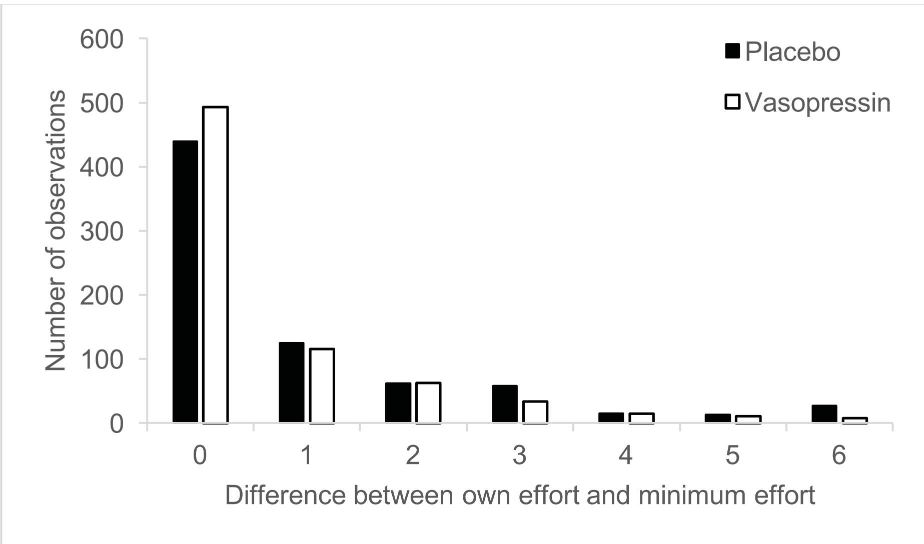

Figure 2: Differences between own effort and minimum effort per group

Table 3: Regression analysis of the influencing factors on effort levels

	Min. effort in t-1		Fairness preferences		Risk preferences	
Intercept	5.377	(0.156)***	5.309	(0.165)***	4.520	(0.206)***
Vasopressin	-0.273	(0.055)***	-0.271	(0.055)***	-0.250	(0.058)***
Min. effort in t-1	0.213	(0.029)***	0.210	(0.029)***	0.319	(0.033)***
Fairness preferences			0.149	(0.077)*	0.270	(0.083)***
Risk preferences					0.305	(0.159)*
N	1152		1152		1152	
Marginal R^2	0.09		0.08		0.18	
Conditional R^2	0.48		0.49		0.51	

Note: Values stand for the estimate, values in brackets are standard errors and stars indicate significance levels with * : $p < 0.10$; ** : $p < 0.05$ and *** : $p < 0.01$

Next, the reasons for the differences in effort levels (see Table 2) was investigated by conducting regressions that were designed to predict the effort level of each subject in the current period. We controlled for repeated measures by estimating generalized linear mixed models. We found that it was not risk preferences, but vasopressin and fairness preferences, that influenced the observed effort levels the most. Namely, the minimum effort played in the previous period had a significant impact on the observed behavior, regardless of what other parameters we added to the regression. The same held for vasopressin. Adding only fairness preferences did not really improve the quality of the model (both marginal and conditional R^2 remained the same as with the estimate without the parameter). Only adding both fairness and risk preferences, to the estimate resulted in slightly higher R^2. As such, the results indicated that fairness preferences have a strongly significant influence, while risk preferences have a minor impact.

5 Discussion

We found that subjects in a minimum effort game chose different effort levels according to the drug they received, the minimum effort level in their group in the previous period and their fairness preferences. The remainder of this paper will examine the various aspects of this result.

Impact of risk preferences: As motivated when introducing the minimum effort game, we expected risk preferences to have a significant impact on the observed behavior. Namely, as the subjects faced no risk when resorting to the minimal possible effort level, their risk of being exploited was maximal when they chose the highest possible effort level. However, according to our regression analysis, the impact of risk preferences on the chosen effort level was minimal. This result supports the notion that cultural norms impact the behavior of subjects. The subjects risk preferences, individual properties of the subject, did not seem to influence behavior. However, fairness preferences, subject properties that are definitely influenced by society, did influence behavior.

Impact of sunlight: In the introduction to this paper, we discussed related literature that clearly shows that sunlight increases the levels of hormones in the human body. However, we were unable to completely exclude the impact of sunlight on the results of this experiment. As experimenters, we cannot control for the sunlight the subjects experienced during the hours prior to the experiment. We did everything to minimize this influence: (1) We conducted the experiment in a laboratory below ground level, such that only artificial light - which does not impact hormone levels - lit the laboratory; (2) The 30 minutes spent completing questionnaires prior to the beginning of the experiment served to reduce the impact of the sunlight the participants were exposed to prior to the experiment; (3) We ensured that subjects from both treatment groups (placebo and vasopressin) sat in the same rooms (below ground level), at the same time and waited together prior to the experiment. In this way, we expected to minimize the impact of sunlight for the purpose of our treatment comparisons.

Additional factors influencing hormone levels: Vasopressin levels are not only subject to sunlight, as stated in the introduction, but also to gender, day of menstrual cycle (Forsling et al. 1981), and other aspects. This study did not attempt to differentiate for each of these factors. To ensure our results were as universal as possible, we minimized the impact of such aspects. Namely, we (1) excluded most aspects by conducting the experiments with male subjects only, and (2) reduced the impact of sunlight. We leave the specific analysis of influencing factors on vasopressin levels to medical practitioners. Nevertheless, controlling for corresponding attributes would also be interesting in economic experiments. That is, one could repeat our experiments with subjects from both genders, compare the impact of daylight lamps; i.e. lamps mimicking the properties of daylight, and traditional lamps, and test female subjects at different stages of their menstrual cycle.

Hormones and economic behavior: As we have shown, vasopressin plays a central role in the way the subjects behaved during the game and the decisions they made. As daylight influences the levels of vasopressin in the body, differences in the behavior of people between summer and winter, and in countries close to and far from the equator are likely. Based on our results, we argue that is not sufficient to conduct experiments in some countries of Europe, the United States, and Israel, but there is a requirement to place a stronger focus on reproducing experimental results throughout the globe; e.g., by accepting repetitions of existing studies for publishing.

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Otto von Guericke University Magdeburg
Faculty of Economics and Management
P.O. Box 4120 | 39016 Magdeburg | Germany

Tel.: +49 (0) 3 91 / 67-1 85 84
Fax: +49 (0) 3 91 / 67-1 21 20

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