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Peers' choices influence adolescent risk-taking especially when explicit risk information is lacking

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ABSTRACT

This study examines the impact of peers' previous cautious versus risky choices on adolescents' risk-taking depending on the level of information about the risk. Adolescents completed an adaptation of the BART that manipulated social influence (cautious and risky) and risk information (i.e., informed, noninformed). Results showed that social influence impacts adolescents' decisions on the noninformed BART but not on the informed BART. In the noninformed BART, the peers' cautious choices strongly decreased risk-taking and led to greater performance. The peers' risky choices increase adolescents' risk-taking, but this effect is limited to situations involving minimal risk. Thus, social experience may be a specific social context that represents a valuable source of information during adolescence, especially in situations with high uncertainty.

Keywords: Adolescent, Risk-taking, Information level, Peer influence, BART

Introduction

Adolescence is a period characterized by an uptick in many risky behaviors (including substance use, alcohol abuse, drunk driving, physical fights or unprotected sexual intercourse) compared to other developmental periods (Steinberg, 2008). Developmental studies have consistently shown that the socioemotional context is a key factor to comprehending adolescence risk-taking behaviors (Albert & Steinberg, 2011; Blakemore & Mills, 2014; Casey et al., 2008; Habib et al., 2013; Steinberg, 2008). Indeed, most risky behaviors among adolescents occur in the presence of peers, who seem to be the greatest source of influence at this age (Berndt, 1979; Larson et al., 1996; Meyer & Anderson, 2000; Utech & Hoving, 1969). Although previous studies have demonstrated that the presence of peers increases both

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immediate reward sensitivity and risk-taking behaviors specifically during adolescence (Chein et al., 2011; O'Brien et al., 2011; Weigard et al., 2014), less is known about the direct influence of peers' choices on adolescents' risk-taking. However, in most everyday life situations, peers are not only passive observers but also provide advice or explicit encouragement based on their own experience to influence the decisions of others. Therefore, the aim of the present study is to examine whether peers' cautious or risky previous choices increase or decrease risk-taking behaviors in adolescents.

There is growing evidence from both behavioral and neurodevelopmental studies that peer presence has a specific effect during adolescence in terms of enhancing reward sensitivity (Casio et al., 2015; O'Brien et al., 2011; Silva et al., 2015; Smith, Steinberg, et al., 2014; Weigard et al., 2014) and increasing risk-taking behaviors (Chein et al., 2011; Gardner & Steinberg, 2005; Smith, Chein, et al., 2014). For example, using a computerized risky driving task, Chein et al. (2011) reported that risk-taking behaviors in the presence of peers increased among adolescents but not young adults. Moreover, neuroimaging results indicated that the risk-promoting effect of peer presence observed in adolescents was associated with enhanced activation in the brain regions that are known to be implicated in reward sensitivity, i.e., the ventral striatum and the orbitofrontal cortex. In contrast, the prefrontal brain regions involved in executive control, including inhibitory control, was not influenced by the presence of peers in either adolescents or adults (Chein et al., 2011). These findings could be interpreted along the framework of the dual systems model (Steinberg, 2008), a model that proposes that adolescent risk-taking propensity is linked to an imbalance between the relative maturity of brain structures involved in incentive processing and the relative immaturity of the brain structures involved in executive control. Accordingly, Chein et al.'s neural findings (2011) suggest that peer presence increases adolescents' risk-taking behaviors by heightening the motivational salience of the potential immediate rewards rather than by decreasing inhibitory

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control ability. Beyond an enhanced reward sensitivity, socioemotional context seems to modulate risk-taking by a reduced sensitivity to complex negative emotion such as regret (Habib et al., 2013).

However, one can observe several discrepancies regarding the manipulation of peers' influence across studies. While peers are sometimes fictive and anonymous (Smith, Chein, et al., 2014; Weigard et al., 2014), some studies have used real peers who can sometimes communicate with participants and receive (or not) instructions to avoid comments that might unintentionally bias participants' behavior (Chein et al., 2011; Gardner & Steinberg, 2005; O'Brien et al., 2011). Thus, it is still unclear whether peer presence *per se* impacts adolescents' choices (Centifanti, Modecki, MacLellan & Gowling, 2016, Somerville et al., 2018). In this vein, two studies have suggested that peer observation alone does not increase the risk-taking behaviors of adolescents and young adults when controlling for peer intervention. Indeed, adolescents' risk-taking behaviors increase when peers provide risky advices but not when the peers are merely present (Haddad et al., 2014; Reynolds et al., 2013). In sharp contrast with these studies, Centifanti et al. (2016) showed that passive peer presence can also influence adolescents' risk-taking behaviors to a lesser extent than peer encouragement. Peers' behaviors, in addition to their presence or advice, are reliable predictors of many risky behaviors in adolescence (Varela & Pritchard, 2011), such as alcohol, drug and tobacco use (Beal et al., 2001; Jackson et al., 2014; Maxwell, 2002; Moon et al., 2014; Teunissen et al., 2012, 2013; Tucker et al., 2014), sexual intercourse (Beal et al., 2001; Holman & Sillars, 2012) or risky driving (Carter et al., 2014; Cascio et al., 2015; Shepherd et al., 2011; Simons-Morton et al., 2011, 2012).

Taken together, these experimental studies have strongly contributed to a better understanding of the role of distinct social contexts in reward sensitivity and risk-taking during adolescence. Nevertheless, most of these studies have mainly focused on the negative impact

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of social contexts on risk-taking (Haller et al., 2018). Peers' choices might also reduce youths' risk-taking behaviors and provide a preventive message for risky situations in daily life (Maxwell, 2002). Empirical support for this assumption was provided by a study showing that exposure to anti-alcohol norms (i.e., safe previous choices of peers) decreases adolescents' willingness to drink compared to pro-alcohol norms (i.e., risky previous choices of peers) (Teunissen et al., 2012, 2013, 2016). Additional evidence of the positive role of peers' influence was provided by Centifanti et al. (2016). In a simulated driving task, adolescents experimented with fewer crashes when they were in the presence of peers who reported a low risk preference. However, other investigations provided opposite results. For example, Haddad et al. (2014) found that adolescents, in contrast with adults, do not follow safe advice from peers (i.e., encouragement to choose a cautious gamble associated with a lower but more likely reward). In the same way, virtual peers' advice seems to enhance adolescents' gambling behaviors compared to a control condition in which adolescents solve tasks alone (van Hoorn et al., 2017). Nevertheless, this increased magnitude depends on the type of advice (i.e., higher bets when they were given high advice compared to low advice). According to the authors, gambling behaviors varied based on social norms. Adolescents may conform to social norms that involve risky behaviors to be accepted by peers.

Notably, all these studies used situations that differ according to the level of uncertainty. They revealed that peer influence increases (or decreases) risk-taking in both informed situations (i.e., with explicit information about the probabilities of the potential outcomes) (Smith, Chein, et al., 2014) and noninformed situations (i.e., when some information about the probabilities is lacking and has to be learned from feedback) (Cavalca et al., 2013; Chein et al., 2011; Gardner & Steinberg, 2005; Haddad et al., 2014 ; Reynolds et al., 2013). However, other studies indicated that adolescents' choices highly depend on the level of uncertainty and underlined the necessity to examine whether peer influence also depends on uncertainty

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(Blankenstein et al., 2016; Tymula et al., 2012; van den Bos & Hertwig, 2017). For example, Blankenstein et al. (2016) provided evidence that peers' choices increased risk-taking in informed situations but not in noninformed situations among adolescents. Critically, other studies have provided discrepant results by showing that the effect of peers' advice increased as the level of uncertainty of the situation increased (van Hoorn et al., 2016). This might suggest the need for an alternative hypothesis. Given that adolescents failed to learn from the feedback they received in noninformed situations (Blankenstein et al., 2016; Cassotti et al., 2014; Osmont et al., 2017; Van Duijvenvoorde et al., 2012, 2013), they might be more inclined to rely on information coming from an external source in the social environment. Thus, specific social contexts such as previous peers' experience might provide social information that is expected to directly modulate choices. Consequently, peer experience might be more pronounced when explicit information about risk is lacking (Osmont et al., 2017), especially during adolescence. This is relevant considering social learning theory, which postulates that learning rests on the observation of experiences, beliefs, behaviors and consequences of others (Bandura, 1969). To our knowledge, only one study has examined the role of previous peers' choices when adolescents have to choose between a risky gamble and a safer gamble, with various levels of uncertainty (Braams, Davidow & Somerville, 2019). Interestingly, these results showed that adolescents follow anonymous peers' choices – especially when they promote the choice of the safer gamble – but this effect did not depend on the level of uncertainty.

Therefore, the abovementioned studies support the need to further explore specific peer influence contexts depending on the level of uncertainty with a direct comparison between informed and noninformed situations.

The current study

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Taken together, previous studies have shown that risk-taking is impacted by both peer presence (Chein et al., 2011; Gardner & Steinberg, 2005; Smith, Chein, et al., 2014; O'Brien et al., 2011; Smith, Steinberg, et al., 2014; Weigard et al., 2014) and the advice of live or virtual observant peers (Cavalca et al., 2013; Reynolds et al., 2013; Teunissen et al., 2016; van Hoorn et al., 2014). However, less is known about how peers' previous experiences influence risk-taking among adolescents. Therefore, the present study investigates the impact of peers' cautious versus risky choices on middle adolescents' risk-taking behavior in both informed and noninformed situations.

In this context, we designed an adaptation of the Balloon Analogue Risk Task (BART) (Osmont et al., 2017) to measure risk-taking behavior depending on the level of risk information (i.e., informed, noninformed) and peers' influence (i.e., control, peers' cautious choices and peers' risky choices). The BART, initially proposed by Lejuez et al. (2002), is a valid measure because it was designed to measure a gradual risk-taking behavior rather than a single choice between a safe and a risky option (Blankenstein et al., 2016; Braams et al., 2019). Moreover, numerous studies have reported that risk-taking during the BART was positively related to the self-reported occurrence of real-life risky behaviors (Cavalca et al., 2013; Dean, Sugar, Hellemann, & London, 2011; Lejuez, Aklin, Zvolensky, & Pedulla, 2003). As in the original version of the BART, adolescents in our study were required to accumulate as many points as possible by inflating balloons associated with various break points and colors. In the informed condition, explicit information about the match between balloons' resistances and colors was provided, while adolescents had to learn this matching based on the feedback received in the noninformed version of the task. Moreover, the social conditions consisted of information about the choices of three same-sex classmates who previously completed the same task; these social conditions were designed to promote either risky or cautious choices. After each trial (saving points or explosion), participants completed a 7-point scale measuring their satisfaction with

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the outcome.

We focused on adolescents aged 13 to 15 years for two reasons. First, previous studies have shown that middle adolescence is an especially significant period for the development of the capacity to resist peer influence. Indeed, the field of experimental social psychology has revealed that developmental changes in social conformity follow an inverted U-shaped pattern with a peak at 14-15 years of age (Berndt, 1979), and the ability to resist pressure from peers increases linearly after age 14 (Steinberg & Monahan, 2007). Second, using the same adaption of the BART without peer influence, Osmont et al. (2017) showed a specific impairment of feedback-based learning ability during middle adolescence. Indeed, adolescents aged 14 to 16 years failed to adjust their risk-taking behaviors to the balloon resistance in the noninformed condition when using only their own experience. Given these specific learning difficulties, we believe that there is a critical need to examine whether previous experiences of peers may impact the development of a qualitative representation of risk level in ambiguous circumstances during middle adolescence.

We reasoned that if previous peers' choices, similar to peer presence, influence risk-taking by emotional modulation (enhancing reward sensitivity and reducing loss sensitivity) (Chein et al., 20011; Habib et al., 2013), then satisfaction should be higher after saving points and after explosions in the two influence conditions compared to the control condition. Moreover, risk-taking should increase in the two influence conditions compared to control, regardless of information level. In contrast, if adolescents used the group for guidance in ambiguous situations (Cassotti et al., 2014; Osmont et al., 2017), peers' previous choices should modulate risk-taking by a conformism or social learning process (Bandura, 1969). Then, the number of balloon explosions in the BART should increase when peer choices encourage risk-taking and decrease when peer choices promote cautious decisions, especially in the noninformed condition. Thus, previous peers' choices could reduce difficulty in adjusting

behaviors based on the risk level in the noninformed compared to the informed BART among adolescents.

Method

Participants

A total of 132 8th grade adolescents, aged 13 to 15 years old, were recruited in a French secondary school (mean age = 13.51, SD = .68; 64 males). All of the adolescents provided parental written consent and informed consent and were tested in accordance with national and international norms governing the use of human research participants. The institution that granted permission for the following experiments is the faculty of psychology of the Sorbonne Paris Cité University. Participants were randomly assigned to one of six experimental conditions: 2 information levels and 3 social conditions (Noninformed-No influence: N=23, mean age = 13.82, SD = .89, 9 males; Noninformed-Cautious influence: N=24, mean age = 13.5, SD = .59, 14 males; Noninformed-Risk influence: N=22, mean age = 13.64, SD = .73, 13 males; Informed-No influence: N=29, mean age = 13.31, SD = .47, 15 males; Informed-Cautious influence: N=19, mean age = 13.53, SD = .70, 6 males; Informed-Risk influence: N=15, mean age = 13.26, SD = .59, 7 males). Statistical analyses did not reveal significant differences in the sex distributions between conditions ($p = .42$, *Fischer exact test*). We did not collect data regarding parental education levels, but the school was located in a middle-class neighborhood in a Parisian suburb. The sample size was determined a priori by running a power analysis using G*Power 3.1.9.2 (Faul et al., 2009), revealing that a minimum of 114 participants would be needed to detect a small effect size of 0.2 (according to Cohen's effect size conventions and based on previous studies reporting medium to large effect sizes of the social influence on risk taking, see for example Chein et al., 2011; O'Brien et al., 2011) within

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a 3 (social influence condition: control, cautious influence, risky influence) x 2 (information levels: informed vs. noninformed) x 3 balloon resistances: low, medium, high) mixed-design analysis of variance (ANOVA) with power ($1 - \beta$) set at .80 and α set at .05.

Design and procedure

Participants completed a new computerized decision-making task (Osmont et al., 2017) adapted from the BART (Lejuez et al., 2002). The level of risk probability information (i.e., informed, noninformed) and social influence (i.e., control, peers' cautious choices and peers' risky choices) were manipulated. Each trial started with a small simulated balloon at the center of the screen. Participants had to inflate the balloon to win chips (Fig. 1). A left mouse-click inflated the balloon and was rewarded by a chip (worth 1, 5 or 10 points) collected in a temporary bank (balloon shown in Fig. 1). However, the balloon could explode at any time: if participants pumped the balloon beyond its break point, they would lose the points accumulated in the temporary bank. Then, a "pop" sound would be generated, and the next uninflated balloon would appear. Before the explosion, participants could transfer all the points in a definitive bank by clicking the right mouse button. Any transfer or explosion resulted in the next balloon.

This adaptation distinguished 3 balloon colors (i.e., yellow; blue or pink) that correspond to 3 balloon resistance levels (low, medium, or high explosion threshold). The matching of resistance with colors was counterbalanced. The low-resistance balloons were constrained to explode between 3 and 7 pumps (i.e., low explosion threshold), the medium-resistance balloons exploded between 8 and 12 pumps (i.e., medium explosion threshold), and the high-resistance balloons exploded between 13 and 17 pumps (i.e., high explosion threshold). A total of 54 balloons were presented by combining the 3 resistance levels (i.e., low, medium, high) and the 3 chip values (1 point, 5 points or 10 points). The exact explosion

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thresholds and the order of balloons were randomly fixed before the study and were the same for all participants.

We created two information level conditions, but the features of the explosion probabilities were strictly constant between the informed and noninformed conditions. In the informed condition, a gauge depicted categorical information about the balloons' resistance. The proportion of red or green in the gauge reflected the three levels of resistance (a large majority of red indicated the low-resistance balloons, half red and half green indicated the middle-resistance balloons, and a large majority of green indicated the high-resistance balloons). Participants were informed that a gauge represented an estimation of the balloon's resistance level and that they had to adapt their choices based on the resistance of balloons. In contrast, in the noninformed condition, a gray cover hid the gauge (see Fig. 1). Thus, the participants received the same information except that a gray cover hid the gauge, so they had to learn to adapt their choices based on the resistance of balloons. In fact, they had to learn the matching of the colors with resistance levels based on the feedback they received (see the entire instructions in supplementary material).

[FIGURE 1]

Participants were randomly assigned to one of 3 conditions: a control condition (i.e., no indication about peers' choices), a risky influence condition (i.e., presentation of peers' risky choices) or a cautious influence condition (i.e., presentation of peers' cautious choices). First, the control group completed the task. Then, 3 male and 3 female names for each class were randomly selected in this control group and used to design the two influence conditions. In both social conditions, the participants were informed that they could see the responses of three same-sex classmates that had previously completed the exact same task. On the upper left

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corner of the screen, the names of the three same-sex classmates were written, and a warning light was associated with each name. For each step of the game, a green warning light informed participants that the classmate kept inflating the balloon, while a red warning light indicated that the classmate stopped inflating the balloon and saved his or her points (see Fig. 1). Classmates' choices were a designed manipulation aimed at promoting either risky or cautious behavior. In the cautious influence condition, the peers' warning lights turned red below the minimum break point of each resistance (i.e., peer 1: after the minimum break point; peer 2: after the minimum break point minus 1 pump; peer 3: after the minimum break point minus 2 pumps). Following the same structure, the peers' warning lights turned red just below the maximum break point of each resistance in the risky influence condition (peer 1: after the maximum break point; peer 2: after the maximum break point minus 1 pump; peer 3: after the maximum break point minus 2 pumps). Table 1 displays the exact peers' choices for each influence and resistance condition. The exact moment that the three peers stopped inflated balloons was counterbalanced between trials.

[TABLE 1]

Given that the exact explosion thresholds and the order of balloons were the same for all participants in this adaptation, we decided to use the mean number of explosions to measure risk-taking and the mean number of points accumulated per balloon to determine whether choices were advantageous or disadvantageous. Moreover, after each balloon (i.e., just after the participants transferred their points or after an explosion), participants completed a 7-point emotional Likert scale (i.e., after having seen your outcome, how do you feel?) ranging from 1 (i.e., unhappy) to 7 (i.e., happy).

Results

We conducted 3*2*3 ANOVAs with the balloon explosions (i.e., the measure of risk-taking in this adaptation of the BART) and the number of points accumulated (i.e., to determine whether choices are advantageous or disadvantageous) as dependent variables, 3 social influence conditions (control, cautious influence, risky influence) and 2 information levels (informed, noninformed) as two between-subjects factors and the 3 balloon resistances (low, medium, high) as a within-subjects factor. (The pump analysis is available in the supporting material). Table 2 displays the descriptive data (means and standard deviations) for each condition.

[TABLE 2]

Explosion analysis

ANOVA revealed a resistance x social influence x information level interaction, $F(4,252) = 3.24$, $p = .01$, $\eta_p^2 = .05$.

To explore this interaction, we conducted two distinct ANOVAs for the informed and noninformed conditions, with social influence and the balloon's resistance as factors (Fig. 2).

In the informed condition, the ANOVA revealed a main effect of balloon resistance ($F(2,120) = 21.28$, $p < .001$, $\eta_p^2 = .26$), indicating that balloon explosions decreased as the balloons' resistance increased, but neither the main effect of social influence ($F < 1$) nor the resistance x social influence interaction ($F(4,120) = 1.51$, $p = .20$) reached statistical significance.

In the noninformed condition, this analysis revealed a main effect of balloon resistance ($F(2,132) = 236.71$, $p < .001$, $\eta_p^2 = .78$), indicating that the number of balloon explosions decreased as the balloon resistance increased. There was a main effect of social influence (F

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(2,66) = 17.02, $p < .001$, $\eta_p^2 = .34$), revealing that participants exploded fewer balloons in the cautious influence condition than in the control condition ($t(45) = 4.28$, $p < .001$, $d = 1.28$) and in the risky influence condition ($t(44) = 6.55$, $p < .001$, $d = 1.97$), but there were no differences between the risky influence and control conditions ($t(43) = .48$, $p = .62$). However, this effect was moderated by a resistance x social influence interaction ($F(4,132) = 15.29$, $p < .001$, $\eta_p^2 = .32$). Student's t-tests corrected with the Holm–Bonferroni method revealed that participants exploded fewer low-resistance and medium-resistance balloons in the cautious influence condition than in the control condition (low-resistance: $t(45) = 6.71$, $p < .001$, $d = 2$; medium-resistance: $t(45) = 3.13$, $p = .02$, $d = .93$) and in the risky influence condition (low-resistance: $t(44) = 6.85$, $p < .001$, $d = 2.07$; medium-resistance: $t(44) = 4.28$, $p < .001$, $d = 1.29$). There were no differences between the risky influence and control conditions for the low-resistance ($p = .53$) and medium-resistance ($p = .70$) balloons. For the high-resistance balloons, participants exploded more balloons in the risky-influence condition than in the control condition ($t(43) = 2.54$, $p = .05$, $d = .77$), but there was no significant difference between the control and cautious influence conditions ($t(44) = 1.85$, $p = .35$) or between the cautious influence and risky influence conditions ($t(45) = .81$, $p = .85$, $d = .24$).

[FIGURE 2]

An additional analysis was conducted to examine the effect of information level depending on social influence. We conducted 3 distinct ANOVAs for the control, cautious and risky conditions, with the information level and the balloon's resistance as factors.

In the control condition, the ANOVA revealed a main effect of balloon resistance ($F(2,100) = 160.10$, $p < .001$, $\eta_p^2 = .65$) and a main effect of information level ($F(1,50) = 4.82$, $p = .03$, $\eta_p^2 = .09$). However, there was a resistance x information level interaction ($F(2,100) = 32.72$, $p <$

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.001, $\eta_p^2 = .15$). Student's t-tests corrected with the Holm–Bonferroni method revealed that participants exploded more low-resistance balloons in the noninformed than in the informed condition ($t(50) = -5.94, p < .001, d = 1.65$) but fewer high-resistance balloons in the noninformed than in the informed condition ($t(50) = 2.70, p = .02, d = .75$). There were no differences between the noninformed and informed conditions for medium resistance ($p = .45$). In the cautious influence condition, the ANOVA revealed a main effect of balloon resistance ($F(2,82) = 19.73, p < .001, \eta_p^2 = .31$) but no main effect of information level ($F(1,41) = 3.14, p = .08, \eta_p^2 = .07$). However, there was a resistance x information level interaction ($F(2,82) = 3.06, p = .05, \eta_p^2 = .05$). Student's t-tests corrected with the Holm–Bonferroni method revealed that participants exploded fewer medium-resistance balloons in the noninformed condition than in the informed condition ($t(41) = 2.70, p = .03, d = .83$). There were no differences between the noninformed and informed conditions for low-resistance ($p = .62$) and high-resistance balloons ($p = .11$).

In the risky influence condition, the ANOVA revealed a main effect of balloon resistance ($F(2,70) = 49.19, p < .001, \eta_p^2 = .50$) and a main effect of information level ($F(1,35) = 10.06, p = .003, \eta_p^2 = .22$). However, there was a resistance x information level interaction ($F(2,70) = 13.89, p < .001, \eta_p^2 = .14$). Student's t-tests corrected with the Holm–Bonferroni method revealed that participants exploded more low-resistance balloons in the noninformed condition than in the informed condition ($t(35) = -6.82, p < .001, d = 2.28$). There were no differences between the noninformed and informed conditions for medium-resistance ($p = .27$) and high-resistance balloons ($p = .41$).

Analysis of points

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An ANOVA examining the mean number of accumulated points per balloon revealed a main effect of the balloons' resistance ($F(2,126) = 1238.22, p < .001, \eta_p^2 = .91$), indicating that the number of points increased as the resistance increased. There was also a marginal main effect of uncertainty level ($F(1,126) = 3.24, p = .07, \eta_p^2 = .03$), indicating a lower number of points in the noninformed condition than in the informed condition. There was also a main effect of social influence ($F(2,126) = 10.14, p < .001, \eta_p^2 = .14$), such that participants accumulated more points in the cautious influence condition than in the control condition ($t(93) = 3.76, p < .001, d = .78$) and the risky influence condition ($t(78) = 3.63, p < .001, d = .83$). The analysis did not reveal any significant interaction between resistance and information level ($F < 1$), between resistance and social influence ($F(4,252) = 1.33, p = .26$), or between resistance, information level and social influence ($F < 1$). However, there was an interaction between social influence and information level ($F(2,126) = 6.44, p = .002, \eta_p^2 = .09$, Fig. 3). Student's t-tests corrected with a Bonferroni procedure revealed that in the noninformed condition, adolescents collected more points in the cautious influence condition than in the control condition ($t(45) = 5.44, p < .001, d = 1.62$) and the risky influence condition ($t(44) = 4.15, p < .001, d = 1.15$). There was no significant difference between risky influence and control conditions ($t(43) = 1.45, p = .62$). In the informed condition, the t-test did not reveal any differences between either social influence condition (all $p > .60$). Additional Student's t-tests corrected with a Bonferroni procedure revealed that for the control condition, participants collected more points in the informed than in the noninformed version ($t(50) = 4.16, p < .001$). There was no significant difference between the informed and noninformed version for the cautious influence condition ($t(41) = -1.27, p = .42$) and the risky influence condition ($t(35) = .98, p = .33$).

[FIGURE 3]

Emotion scale analysis

To examine whether peers' cautious or risky choices impact emotional feelings after gains (saved points) or balloon explosions, we conducted an ANOVA on the mean emotional score (7 points) with information level (2 levels: informed, noninformed) and social influence (3 conditions: cautious influence, risky influence, control) as the between-subjects factors and feedback (2: saved points, balloon explosion) as the within-subjects factor. The results revealed a main effect of feedback ($F(1,126) = 704.52, p < .001, \eta_p^2 = .85$), indicating that participants expressed more positive emotions after a gain than after a balloon explosion (saved points: $M = 4.98, SD = .97$; balloon explosion: $M = 2.17, SD = 1.32$). There was also a main effect of social influence ($F(2,126) = 5.65, p = .004, \eta_p^2 = .08$). Participants expressed more positive emotions in the cautious influence condition ($t(93) = 3.92, p < .001, d = .81$) and risky influence condition ($t(87) = 2.60, p = .02, d = .55$) than in the control condition (control: $M = 3.62, SD = .75$; cautious influence: $M = 4.38, SD = 1.14$; risky influence: $M = 4.10, SD = 1.02$) but risky and cautious conditions did not differ significantly ($t(78) = 1.13, p = .26, d = .26$). However, the ANOVA revealed no main effect of information level ($F < 1$), and no significant interaction was found between social influence and information level ($F < 1$), between feedback and information level ($F(1,126) = 1.20, p = .27$), between feedback and social influence ($F < 1$), or between feedback, social influence and information level ($F < 1$).

Discussion

The present study aimed to clarify whether cautious vs. risky choices by peers influence risk-taking in adolescents in both informed situations (i.e., with explicit information about the probabilities of the potential outcomes) and noninformed situations (i.e., when some

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information about the probabilities is lacking). Three major findings emerged from this research. First, cautious choices by peers had a strong effect on adolescents' decisions by decreasing their engagement in risk-taking when a low or moderate risk was beneficial. Second, risky choices by peers increased risk-taking among adolescents, but this effect is limited to situations involving minimal risk (i.e., high-resistance balloons). Third, peers' previous choices influenced adolescents' decisions specifically on the noninformed BART but not on the informed BART. Finally, cautious and risky choices by peers increased positive feelings compared to the control condition.

First, our results highlighted the effect of peers' previous choices when information about risk level is lacking, especially when peers engaged in safe behaviors. Indeed, peers' cautious choices had a robust positive effect on adolescents' risk-taking in the noninformed condition. When told about cautious choices by peers, participants exploded fewer balloons and collected more points than in the control condition and the risky influence condition when low or moderate risks were advantageous (for the low- and medium-resistance balloons). Thus, our results confirmed that peers' influence can stimulate cautious behaviors, leading to advantageous decisions among 13- to 15-year-old adolescents. In accordance with our results, previous investigations showed that exposure to anti-alcohol or prosocial norms led to a lower likelihood of drinking (Teunissen et al., 2012, 2013) and more prosocial decisions in teenagers (van Hoorn et al., 2014). As such, our findings extend these studies by underlining the positive impact of social influence even if peers are not physically present as well as a distinct kind of influence: participants received information about their peers' previous experience rather than being directly confronted with their peers' advice. Then, even if previous work has been overly focused on risk and negative social influence, peers can also have a pro-social impact and improve cautious behaviors.

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On the other hand, peers' risky choices had a moderate impact on risk-taking: adolescents exploded more balloons when they were told about peers' risky choices only for the high-resistance balloons (i.e., a minimal risk level). This might be surprising given that previous studies reported greater levels of risk-taking in adolescents resulting from peers' presence (Gardner & Steinberg, 2005; O'Brien et al., 2011; Smith, Chein, et al., 2014) and peers' encouragements (Cavalca et al., 2013; Cohen & Prinstein, 2006; Haddad et al., 2014; Reynolds et al., 2013). However, our results are in line with previous studies showing that peer influence enhanced risk-taking in the BART only when balloons with a large range of breakpoints were used (Cavalca et al., 2013; Reynolds et al., 2013; Yechiam et al., 2008). The evidence of the influence of peers' risky choices only for high-resistance balloons (i.e., a low risk level) might also indicate that adolescents need some feeling of safety to follow risky influence from peers. Moreover, Braams et al. (2019) showed that cautious peer experience has a stronger effect than risky experience among later adolescents.

Interestingly, our results in the informed BART are in sharp contrast with those of Braams et al. (2019) and Blankenstein et al. (2016). While Braams et al. (2019) did not find evidence of differential influence of peers' previous choices depending on uncertainty level, Blankenstein et al. (2016) found an impact of risk-taker peers' choices on risk propensity but not on ambiguity propensity in adolescents. In contrast, our adolescents did not refer to social information when the matching between resistances and balloon colors was directly available. Indeed, in the informed condition, peers' risky and cautious choices did not influence adolescent risk-taking behaviors. These discrepancies might be explained by the design of the task used in these studies. Contrary to Braams et al. (2019) and Blankenstein et al. (2016) design, BART trials provide information about the following choices. In the noninformed BART, feedback received after each trial (i.e., explosion or collected points) helps participants in building a qualitative representation of risk level for each balloon color. Then, the differential

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effect of peer experience depending on information level could result from a stronger tendency to rely on information coming from an external source in the social environment in ambiguous situations. In accordance with social learning theory (Bandura, 1969), this hypothesis could be especially relevant during middle adolescence, a period associated with specific feedback learning difficulties (Osmont et al., 2017).

The direct comparison between informed and noninformed conditions provides further evidence for this hypothesis. First, in the control condition, we confirm that middle adolescents adjust responses less in the noninformed BART compared to the informed BART (Osmont et al., 2017). Indeed, adolescents failed to adapt risk taking to balloon resistance: they take more risks for breakable balloons and fewer risks for highly resistant balloons in the noninformed BART compared to the informed BART. Then, we examined whether this gap in risk-level adaptation in the noninformed BART compared to the informed BART is modulated by social information. These additional analyses revealed that contrary to the control condition, adolescents did not take more risk for breakable balloons in the noninformed BART compared to the informed BART when they were confronted with peers' previous cautious choices. In addition, they did not take less risk for the high-resistance balloons in the noninformed BART compared to the informed BART when they were confronted with peers' risky previous choices. Therefore, peers' previous choices seem to reduce this gap in risk-level adaptation. Peers' previous risky choices lead adolescents to higher risk-taking when risk is relevant. In contrast, peers' previous cautious choices could lead to less risk-taking when safer choices are relevant, resulting in more cumulated points compared to the control condition in the noninformed BART.

Crucially, the analyses of outcome satisfaction following explosion or cumulated points provided new insights into the specificity of this social context. Our findings indicated that peers' previous choices increase positive feelings compared to the control condition, and this

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effect was observed for both cautious and risky influences. At first sight, this result suggests that the impact of peers' previous choices, similar to peer presence or peer advice, could be explained by a modulation of the cost-benefit evaluation in salient socioemotional contexts (i.e., enhanced reward sensitivity and reduced loss sensitivity) (Chein et al., 2011; O'Brien et al., 2011; Ernst, 2014; Gardner & Steinberg, 2005; Habib et al., 2013; O'Brien et al., 2011; Weigard et al., 2014). However, contrary to peer presence or advice, which increase risk-taking, even in the presence of probabilistic information (Smith et al., 2014), social experience impacts adolescents' choices depending on the nature of this choice and only when information about risk levels is lacking. Here, the reverse effect of peers' cautious versus risky choices on risk-taking behaviors might not exclusively rely on this emotional modulation.

Thus, our results suggest that peer experience is a specific social context that modulates risk-taking by processes distinct from peer presence or peer advice. We assumed that peers' previous choices may modulate risk-taking by a conformism or social learning process (Bandura, 1969). Van Hoorn et al. (2016) concluded that the type of peer advice is the most important factor for decisions with a relatively uncertain outcome because adolescents may conform to social norms in order to be accepted by their peers. Interestingly, in our study, peers' cautious choices reduced risk-taking when low or moderate risk was relevant, whereas peers' risky choices enhanced risk-taking only for the more resistant balloons. The fact that adolescents do not blindly follow peers' risky choices suggested that they are able to resist social conformity when social information is not relevant to the objective feedback received during the task (e.g., peers took many risks for the low-resistance balloons). Contrary to peer advice, peers' previous choices do not involve peers being present and observing participants' choices. The lack of social motivation for change and peer acceptance may explain the relatively weak conformism following peer previous experience. In accordance with the social learning process (Bandura, 1969), social experience may be a specific social context that

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represents a valuable source of information during adolescence, crucially when information about risk level is missing. Additional studies are needed to further explore the processes involved in peers' previous choice influence, for instance, by including social conformity measures or exploring the impact of social experience when peers can observe whether participants conform to their previous choices.

Limitations

Previous studies showed that middle adolescence is an especially significant period for the development of the capacity to resist peer influence (Steinberg & Monahan, 2007). Moreover, using the same adaption of the BART, Osmont et al. (2017) showed a specific impairment of feedback-based learning ability during middle adolescence. Indeed, adolescents aged 14 to 16 years failed to adjust risk-taking to balloon resistance in the noninformed condition from their own experience. Thus, we focused on adolescents aged 13 to 15 years to examine whether previous experiences of peers may impact the development of a qualitative representation of risk level in ambiguous circumstances. In adults, Chung et al. (2015) showed the bidirectional effects of others' choices (risky or safe) on individual risk propensity. Nonetheless, future studies should use a comparison group of late adolescents and young adults to examine whether the magnitude of peers' previous choices influence depends on age.

Another limitation of our design is that peers' risk-taking profiles could affect the results. For example, using the name of a peer known for high daily life risk-taking could reduce design credibility in the cautious condition. However, the 3 peers were randomly selected among participants of the control group who had previously completed the task and were also randomly selected among the classes. Thus, the probability of selecting 3 classmates known for being risk-takers (or cautious) seems relatively low. Moreover, other individual characteristics of peers, such as friendship or popularity, could also impact the tendency to follow peer

influence. Even if several studies showed similar effects of peer influence with anonymous peers as with real peers (Braams et al., 2019; van Hoorn et al., 2016; Weigard et al., 2014) future studies could examine whether previous choices of anonymous peers modulated risk-taking during adolescence. In the same way, parent presence has opposite effects that peers have on adolescent risk taking (Telzer et al., 2015; van Hoorn, McCormick, Rogers, Ivory & Telzer, 2018). There is a critical need to explore the role of previous experience of other sources of influence, such as parents or siblings. In addition, like most previous studies, we only investigated the influence of same-sex classmates. Future studies need to assess whether opposite-sex peers influence adolescents' choices in the same way as same-sex peers. Furthermore, peers' previous choices are the only source of information in the noninformed condition. One could question the social nature of previous peers' choices in our design. Further evidence for social influence could be provided by showing that non-social information, for example robots' previous choices, would not impact adolescent risk-taking as much as peers.

Finally, we selected a between-subjects design for two reasons. First, using real classmates, between-subjects appeared more relevant to boost the credibility of peers' choices. Second, previous studies showed a test-retest effect on BART measures (Reynolds et al. 2013). Given that the noninformed BART involves learning to match the colors of balloons to their resistance, a within-subjects design seems less appropriate in our study. Future research should provide further evidence using an adapted within-subject design.

Conclusion

The present study provides evidence that peers can have a positive impact on risk engagement in adolescents. Peers' cautious choices reduce adolescents' risk-taking and increase advantageous decision making. In addition, peers' risky experiences have a lower

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impact, showing that adolescents do not blindly follow peers' risky choices: risky choices increase with risky social influence only when risk-taking appears to be an appropriate strategy. Notably, while peers' previous choices strongly modulated risk-taking when explicit information about risks was missing, adolescents did not consider such social influence in the informed situations. Then, peers' experience, especially cautious experiences, may be a specific social context that represents a valuable source of information, alerting about potential danger and providing better risk-level adjustment. The present finding expands the understanding of the positive influence of the social context on risk-taking during adolescence and offers new directions to investigate how social information might be efficiently used to reduce risk-taking in prevention programs. Given that risky behaviors in daily life often occur when explicit risk information is lacking, awareness campaigns might not only aim to reduce sensitivity to peers' encouragements but might also take advantage of the impact of peers' preventive messages.

Supporting Information

Participants' Instructions and Pump analysis may be found online as additional supporting information.

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Table 1. Description of the 3 peers' choices design for low, medium and high balloon resistance.

| | | | Resistance (explosion thresholds) | | |
|---------------------------|--------|--|--------------------------------------|------------------|-----------------|
| | | | Low (3→7) | Medium (8→12) | High (13→17) |
| | | | General Design | | |
| Cautious Influence | Peer 1 | <i>after the minimum break point</i> | 3 | 8 | 13 |
| | Peer 2 | <i>after the minimum break point minus 1 pump</i> | 2 | 7 | 12 |
| | Peer 3 | <i>after the minimum break point minus 2 pumps</i> | 1 | 6 | 11 |
| Risky Influence | Peer 1 | <i>after the maximum break point</i> | 7 | 12 | 17 |
| | Peer 2 | <i>after the maximum break point minus 1 pump</i> | 6 | 11 | 16 |
| | Peer 3 | <i>after the maximum break point minus 2 pumps</i> | 5 | 10 | 15 |

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Table 2. Descriptive statistics: Mean (standard deviation) numbers of explosions, cumulated points and emotional scale (outcomes' satisfaction ranging from 1 (i.e., unhappy) to 7 (i.e., happy) for each condition.

| | | Informed | | | Noninformed | | |
|--|-----------------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| | | Control | Cautious Influence | Risky Influence | Control | Cautious Influence | Risky Influence |
| Explosions (out of 18 balloons) Mean (SD) | Low-resistance | 7.97 (2.71) | 6.32 (2.65) | 7.00 (2.39) | 13.0 (3.41) | 6.75 (2.98) | 11.86 (1.93) |
| | Medium-resistance | 5.31 (2.47) | 5.05 (2.27) | 4.93 (2.60) | 5.96 (3.59) | 3.37 (1.81) | 6.32 (2.78) |
| | High-resistance | 3.90 (2.32) | 4.42 (3.64) | 4.67 (3.18) | 2.22 (2.10) | 2.71 (2.05) | 3.91 (2.34) |
| | Total (out of 54 balloons) | 17.18 (5.25) | 15.79 (5.57) | 16.60 (6.42) | 21.17 (7.84) | 12.83 (5.32) | 22.09 (4.12) |
| Points (per balloon) Mean (SD) | Low-resistance | 10.01 (2.43) | 10.88 (1.20) | 10.12 (2.44) | 5.88 (4.00) | 10.34 (2.28) | 8.23 (2.70) |
| | Medium-resistance | 27.50 (5.17) | 27.74 (5.94) | 26.42 (3.51) | 23.39 (6.79) | 29.54 (3.94) | 24.66 (5.03) |
| | High-resistance | 44.38 (6.50) | 44.78 (11.88) | 41.64 (9.59) | 39.54 (6.63) | 48.83 (9.51) | 41.19 (8.45) |
| | Total | 27.29 (3.30) | 27.8 (4.96) | 26.06 (4.52) | 22.94 (4.24) | 29.57 (4.11) | 24.69 (3.84) |
| Emotions (7 points scale) Mean (SD) | Gain | 4.60 (.47) | 5.39 (1.04) | 5.37 (1.28) | 4.65 (.82) | 4.84 (1.06) | 5.02 (.78) |
| | Loss | 1.74 (0.80) | 2.13 (1.50) | 2.72 (1.77) | 1.76 (.95) | 2.46 (1.74) | 2.22 (1.03) |
| | Total | 3.68 (.74) | 4.46 (1.08) | 4.45 (1.36) | 3.54 (0.77) | 4.32 (1.20) | 3.87 (.63) |

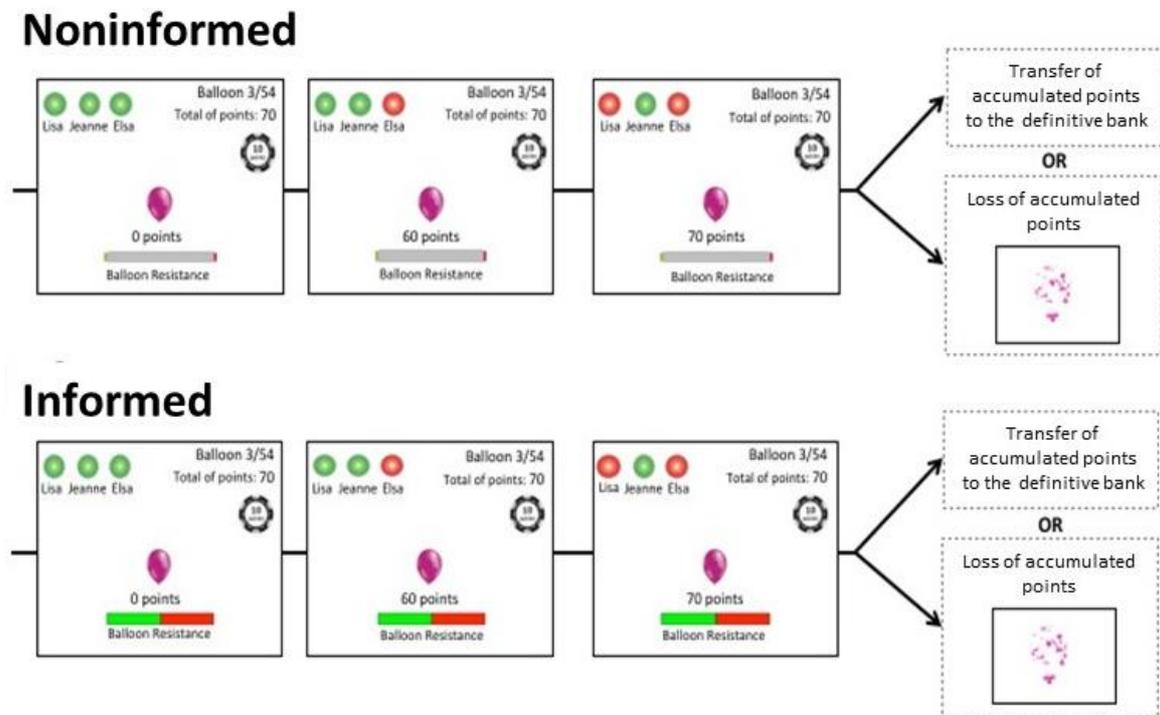


Fig. 1. Sequence of a trial under cautious influence in the noninformed and informed conditions. The red warning lights indicate that Elsa stopped inflating the balloon after 6 pumps and Lisa stopped inflating the balloon after 7 pumps, whereas Jeanne continued to collect points at this step of the game.

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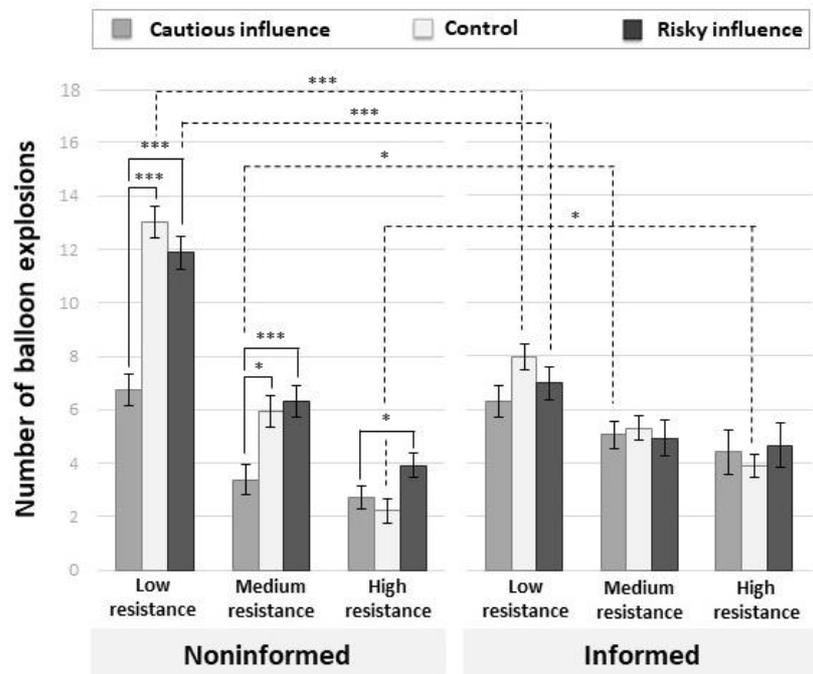


Fig. 2. Number of balloon explosions. Number of explosions (over 18 balloons for each resistance) in the noninformed and informed conditions depending on social influence condition (i.e., control condition, cautious previous peers' choices, risky previous peers' choices) and the balloons' resistance (i.e., low-, medium-, high-resistance). Error bars indicate standard errors.

*: $p < .05$; ***: $p < .001$.

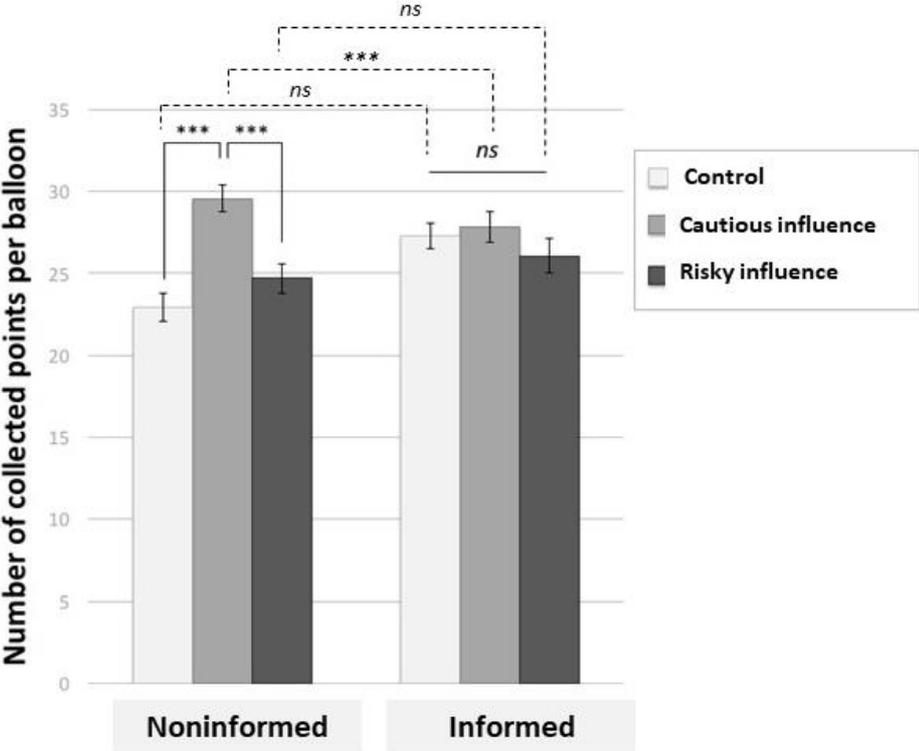


Fig. 3. Mean number of points per balloon. Mean number of points per balloon in the noninformed and informed conditions depending on the social influence condition (i.e., control, cautious influence, risky influence). Error bars indicate standard errors. ***: $p < .001$.

Supporting material

Participants' Instructions

You will play a game where you should collect the most points by inflating balloons and avoiding explosions.

Throughout the game, you will be presented with 30 balloons, one at a time. For each balloon, you can click on the left mouse button, as many times as you want, to increase the size of the balloon. For each pump, you will accumulate a chip of 1, 5 or 10 additional points in a temporary bank. The number of points per chip and the number of points in the temporary bank are displayed on the screen. The more the size of the balloon increases, the more you win points. However, at some point, the balloon will explode. At any point, you can stop pumping up the balloon and click on the right mouse button to move to the next balloon and transfer the accumulated money from your temporary bank to your permanent bank labeled "Total of points." If the balloon explodes before you click on the right mouse button, then you also move on to the next balloon, but all money in your temporary bank is lost.

After each balloon, you will have to complete a scale to indicate your satisfaction level about the outcome for this balloon, ranging from 1 (i.e., unhappy) to 7 (i.e., happy).

There are 3 different colored balloons (10 blue, 10 yellow and 10 pink). Each color corresponds to a balloon resistance level (low, medium, or high explosion threshold).

[Informed condition] *At the bottom of the screen, a gauge indicates an estimation of the balloons' resistance level. The more the gauge is green, the more the balloon is resistant (high threshold). The more the gauge is red, the more the balloon is breakable (low threshold). To win more points, you need to adapt your choices to the resistance of balloons.*

[Noninformed condition] *At the bottom of the screen, a gauge indicates an estimation of the balloons' resistance level. The more the gauge is green, the more the balloon is resistant (high threshold). The more the gauge is red, the more the balloon is breakable (low threshold).*

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However, a gray cover hid the gauge. To win more points, you need to learn to adapt your choices to the resistance of balloons.

Some of your classmates have previously played the same game. In the upper left corner of the screen, three of those classmates' names will be displayed with a warning light each. This warning light will permit you to see their choices. For each step of the game, a green warning light informs you that this classmate kept inflating the balloon, while a red warning light indicates that he/she stopped inflating the balloon and saved his/her points. Your classmates were given the exact same balloons and received the same information as you.

I remind you that your aim is to win the most points as possible.

Pump analysis

We conducted 3*2*3 ANOVAs on the number of pumps, with 3 social influence conditions (control, cautious influence, risky influence) and 2 information levels (informed, noninformed) as two between-factors and the 3 balloon's resistances (low, medium, high) as a within-factor. Table 3 displays descriptive data (means and standard deviations) for each condition.

The ANOVA on the mean number of pumps per balloon revealed a three-way Resistance * Influence * Information interaction, $F(4,252) = 5.31$, $p < .001$, $\eta_p^2 = .08$. To explore this interaction, we conducted two distinct ANOVAs for the informed and noninformed conditions, with social influence and balloon resistance as factors.

In the informed condition, this analysis revealed a main effect of balloon resistance, $F(2,132) = 1073.14$, $p < .001$, $\eta_p^2 = .94$, indicating that the number of pumps increased as the resistance increased (low-resistance: $M = 3.39$, $SD = .54$; medium-resistance: $M = 7.58$, $SD = .98$; and high-resistance: $M = 11.67$, $SD = 1.62$), but there was no main effect of social influence, $F(2,60) = 1.40$, $p = .25$, and there was no resistance x social influence interaction, $F(4,120) = 1.80$, $p = .13$.

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In the noninformed condition, the ANOVA revealed a main effect of balloon resistance, $F(2,132) = 673.69, p < .001, \eta_p^2 = .91$, indicating that the pump number increased as the resistance increased (low-resistance: $M = 3.97, SD = .68$; medium-resistance: $M = 7.59, SD = 1.03$; high-resistance: $M = 10.58, SD = 2.01$). There was also a main effect of social influence, $F(2,66) = 3.84, p < .05, \eta_p^2 = .10$, but this effect was modulated by a resistance x social influence interaction, $F(4,132) = 18.14, p < .001, \eta_p^2 = .35$. Post hoc analysis (Student's t-tests corrected with a Bonferroni procedure) revealed that the pump number is weaker for the low-resistance balloons in the cautious influence condition than in the no influence condition, $t(45) = 6.69, p < .001, d = 1.99$, and in the risky influence condition, $t(44) = 6.84, p < .001, d = 2.06$. There was no significant difference between the risky influence and the no influence conditions, $t(43) = .83, p = .81$. For the medium-resistance balloons, there was no significant difference between influence conditions (all $p > .05$). Finally, participants inflated the high-resistance balloons less in the no influence condition than in the cautious influence condition, $t(45) = 5.46, p < .001, d = 1.63$, and in the risky influence condition, $t(44) = 2.97, p = .02, d = .90$. There was no significant difference between risky influence and cautious influence conditions, $t(44) = 1.67, p = .41$.

Table 3. Descriptive statistics: Mean (standard deviation) numbers of pumps for each condition

| | | Informed | | | Noninformed | | |
|--------------------|-------------------|---------------------|---------------------|---------------------|--------------------|--------------------|--------------------|
| | | Control | Cautious Influence | Risky Influence | Control | Cautious Influence | Risky Influence |
| Pumps Mean (SD) | Low-resistance | 3.54 (.50) | 3.32 (.54) | 3.31 (.60) | 4.38 (.51) | 3.31 (.58) | 4.27 (.32) |
| | Medium-resistance | 7.70 (.89) | 7.81 (.94) | 7.24 (1.13) | 7.47 (1.31) | 7.41 (.59) | 7.90 (1.07) |
| | High-resistance | 11.42 (1.24) | 12.20 (1.60) | 11.37 (2.17) | 9.16 (1.78) | 11.69 (1.37) | 10.85 (2.01) |
| | Total | 17.18 (5.25) | 15.79 (5.57) | 16.60 (6.42) | 7.01 (1.38) | 7.47 (1.35) | 7.67 (1.41) |