# Comparing adults and adolescents regarding the scope insensitivity of value curves: A functional measurement approach*

## Comparación de adultos y adolescentes con respecto al alcance de insensibilidad de las curvas de valor: Un método de medición de funcionamiento

Received: 10 March 2016 | Accepted: 20 June 2016

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**ABSTRACT**

The curvature of the value/utility function has been understood, since D. Bernouilli, as the expression of an attitude towards risk. This perspective was kept in such influential theories of judgment and decision as Prospect Theory, in both its original and cumulative versions (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992). More recently, dual-process interpretations of the value function as a mix of affect and deliberation (Hsee & Rottenstreich, 2004) have proposed that function curvature reflects the operation of affect-based evaluations via an affective focus coefficient indexed by "α" (varying between 0 and 1) in the equation $v = A^{\alpha}S^{1-\alpha}$ (with "v" the subjective value, "A" the intensity of the affective response, and "S" the scope of the stimuli). According to this view, evaluating more hedonic targets results in more curved (scope-insensitive) functions than evaluating instrumental/utilitarian targets, and more affect-oriented subjects exhibit more pronounced curvatures (lower 1α) than deliberation-oriented subjects. These predictions are evaluated in this study and additionally used for an exploratory evaluation of Reyna and Farley's (2006, 2007) proposal that analytical processing and gist/affect-based processing predominate, respectively, in adolescents' and in adults' judgment and decision making. Information Integration Theory was used to establish a model allowing for the functional measurement of subjective value at the (ratio) level required for comparing curvature parameters and computing Loss Aversion coefficients. The outcomes partially favored the prediction of larger curvatures (lower 1- α) and larger loss aversion in more hedonic tasks. However, they did not support the prediction of more scope insensitivity and larger values of loss aversion in adults than in adolescents. As the main suggested difference between adults and adolescents, individual differences in risk attitude appeared to be less polarized towards loss aversion among adolescents in more hedonic tasks.

**Keywords**
Functional Mmeasurement, information Iintegration Ttheory, loss Aaversion, dual-process theories, value Ffunction.

**RESUMEN**

La curva de la función valor/utilidad ha sido comprendida, desde D. Bernouilli, como la expresión de una actitud frente a un riesgo. Este punto de vista se mantuvo vigente en teorías influyentes del juicio y la toma de desiciones en la denominada Teoría de la Perspectiva, tanto en sus versiones originales como las subsecuentes (Kahneman y Tversky, 1979; Tversky y Kahneman, 1992). Más recientemente, las interpretaciones sobre el proceso dual de la función de valor que se muestran como una mezcla entre el afecto y la deliberación (Hsee y Rottenstreich, 2004) han propuesto que la función de la curva representa las evaluaciones basadas en el afecto a través de un coeficiente de enfoque afectivo incluido como "α" (que varía entre 0 y 1) en la ecuación $v = A^{\alpha}S^{1-\alpha}$ (donde "v" es valor subjetivo, "A" es la intensidad de la respuesta afectiva, y "S" es el alcance real de los estímulos). De acuerdo con este punto de vista, la evaluación de los resultados de los más hedonistas muestra una función más encurvada ( insensibilidad al alcance) que la evaluación de los instrumentales / utilitarios, y los más orientados por el afecto muestran una curvatura más pronunciada (inferior 1-α) que los sujetos orientados a la deliberación. Estas predicciones son evaluadas en este estudio y además utilizadas para una evaluación exploratoria de la propuesta de Reyna y Farley (2006, 2007) en la que predomina el procesamiento analítico y el procesamiento síntesis/basado en el afecto, respectivamente, en los juicios y toma de desiciones de los adolescentes y de los adultos. La Teoría de Integración de la Información se utilizó para establecer un modelo apropriado para la medición funcional del valor subjetivo (índice) del nivel requerido para comparar los parámetros de curvatura y calcular los coeficientes de Aversión a la Pérdida. Los resultados favorecieron parcialmente la predicción de curvaturas más grandes (menores que 1- α) y mayor aversión a las pérdidas en las tareas más hedonistas. Sin embargo, no apoyaban la predicción de mayor alcance de insensibilidad y grandes valores de aversión a las pérdidas en los adultos que en los adolescentes. Los resultados más importantes sugieren una diferencia entre adultos y adolescentes, las diferencias individuales de la actitud ante el riesgo parecieron ser menos polarizadas frente a la aversión a las pérdidas entre los adolescentes en tareas más hedonistas.

**Palabras clave**
Medición funcional, teoría de la integración de la información, aversión a la pérdida, teoría de procesos duales, función de valor.

## Para citar este artículo:

Viegas, R., & Oliveira, A. (2016). Comparing adults and adolescents regarding the scope insensitivity of value curves: A functional measurement approach. *Universitas Psychologica, 15* (3), http://dx.doi.org/10.11144 /Javeriana.upsy15-3.caar

Since its proposal by Daniel Bernoulli (1738/1954), the negative curvature of the value/utility function has been understood to incorporate a cautious risk attitude. The link between function curvature and attitude towards risk was maintained and actually reinforced in Prospect Theory (PT: Kahneman & Tversky, 1979) and Cumulative Prospect Theory (CPT: Tversky & Kahneman, 1992), the current “gold standard” of descriptive theories of decision under risk. The introduction by PT of a variable "reference point", separating between the domains of gain and loss, was accompanied by the distinction of two differently curved functions: negatively accelerated for gains, reflecting a risk-averse attitude, and positively accelerated for losses, reflecting a risk-prone attitude (willingness to take risks in order to avoid loss).

Recent dual-process interpretations of the value function as a mix of feeling and calculation (Hsee & Rottenstreich, 2001; Rottenstreich & Shu, 2004) added new parameters associated with the curvature of the function

$$v = A^{\alpha} S^{1-\alpha} \quad (1)$$

with A standing for the intensity of the affective response to a stimulus, α for an “affective focus coefficient”, varying between 0 and 1, and S for the “scope of the stimulus” (its range of variation; see Rottenstreich & Shu, 2004). The higher the value of α, the more affective/emotional the valuation is; the higher 1 - α, conversely, the more deliberative-calculative it becomes. This model thus suggests an interpretation of the function curvature as the resultant of the relative contribution of affective-based processes. Straightforward predictions are that more curved (scope-insensitive) functions will arise with hedonic than with instrumental/utilitarian outcomes, and that more affect-oriented subjects will display more pronounced curvatures (lower 1 - α) than calculation-oriented subjects.

In this study, the first prediction is tested and the second is addressed in an exploratory manner with a link to Reyna and Farley's developmental proposal (2006, 2007) that, along the transition from adolescence to adulthood, experiential/affective processes become increasingly dominant in everyday decisions (as part of a more general process whereby verbatim/analytical representations gradually give way to gist/intuitive ones). However, from a measurement standpoint, ratio scales of subjective value are required for a proper check of these predictions, even if no common unit is needed (with differences in scale units absorbed by $A^{\alpha}$, the estimation of the 1- $\alpha$ exponent can be done under the proviso that the measurement scale has a true zero). This is a rather stringent condition which will be addressed here by means of Functional Measurement (Anderson, 1981, 1982).

A further relevant concept, both in the general context of dual-process views of value and in the particular context of a tentative evaluation of Reyna and Farley's proposal, is that of *Loss Aversion* (LA) (Tversky & Kahneman, 1991, 1992; Köberlling & Wakker, 2005). Commonly taken as an affective (non rational-analytical) component of decisions, LA corresponds to the notion that people are more sensitive to losses than to commensurate gains. While under PT it is modeled as an inflection of the value curve around the reference point, more behavioral approaches to LA have advocated that it should be defined by reference to expected value, allowing for the contribution of probabilities (e.g., Brooks & Zank, 2005). Reported differences between the developmental profile of risk taking for gains and for losses (decreasing for gains, relatively constant for losses) have been credited to the impact of LA (Weller, Levin, & Denburg, 2011). However, conditions for measuring LA are as stringent as those for measuring scope insensitivity, requiring that gains and losses be measured on a scale with a known zero (Viegas, Oliveira, Garriga-Trillo, & Grieco, 2012). Common preference-based methods, such as the probability equivalent, certainty equivalent, or lottery equivalent methods (Hershey & Shoemaker, 1985; see also Wakker & Deneffe, 1996; Abdellaoui, Bleichrodt, & L'Haridon, 2008) cannot handle this requirement (Abdellaoui, Bleichrodt, & Parashiv, 2007, Abdellaoui et al., 2008), which will be tackled here via functional measurement.

The first condition for using FM in this context is documenting the existence of a suitable (in view of the sought metric properties) integration model in the domain of concern (Anderson, 1981, 1982). One such model, allowing for the full characterization of value functions and the computation of LA coefficients, was actually found in earlier studies with a one-roulette game task requiring the integration of uncertain gains and losses (Viegas, Oliveira & Garriga-Trillo, 2009, 2010; Viegas, Oliveira, Garriga-Trillo, & Grieco, 2012). Two variants of this task were used here for comparing adults and adolescents: the "utilitarian" task, where outcomes were utilitarian-instrumental goods, and the "hedonic" task, where outcomes were set to be more affectively charged. Despite remaining uncertainties, the distinction between utilitarian and hedonic goods has made its way into the field of judgment and decision-making. The former are thought of as being primarily assessed on the basis of their instrumentality, the latter on the basis of their emotional/ affective content (Khan, Dhar & Wertenbroch, 2005; O'Curry & Strahilevitz, 2001). Utilitarian goods were operationalized with reference to examples in the concerned literature (e.g., Kahn, Dhar, & Wertenbroch, 2005). Hedonic outcomes were operationalizedsed by monetary prizes allegedly accruing to humanitarian causes, vividly illustrated by upsetting affect-laden images (Slovic, Finucane, Peters, & MacGregor, 2004).

Based on the described dual-processing view of the value function, on the one hand, and on Reyna and Farley's proposal, on the other hand, the following predictions were derived:

1. Both scope-insensitivity and LA should be larger in the hedonic than in the utilitarian task in both the adults' and the adolescents' samples (a straightforward

prediction of the dual-process view of Hsee & Rottenstreich, 2004);

2. The curvature of the value function (degree of scope-insensitivity) should be more pronounced for adults than for adolescents; this should be true, in principle, in both variants of the task;
3. LA should be larger (reflecting a more affective, less neutral, cautious attitude) in adults than in adolescents, and closer to 1 (rather than, for instance, significantly below 1) in adolescents;
4. Based on the suggested developmental trend of increasing prevalence of experiential/affective decision-making, the percentage of loss-averse participants should in principle be higher among adults. This prediction, which concerns interindividual differences, can only be taken as an argument in favor of Reyna and Farley's claim (of a larger contribution of deliberative processes in adolescents) if prediction (3) simultaneously verifies.

## Method

### *Participants*

Adults: 30 undergraduate students aged between 18 to 25 years old (M = 19.1; SD = 1.77) performed on the hedonic task. A second group of 30 students, aged 18 to 33 (M = 19.6; SD = 3.4), performed on the utilitarian task. They were all enrolled in exchange for course credits and were unaware of the purposes of the experiment. Adolescents: 18 students from a secondary school aged between 14 and 15 years old (M = 14.1; SD = 0.32) performed voluntarily on both the hedonic and the utilitarian tasks (counterbalanced across subjects; between-tasks interval varying from one to one and a half months) after written informed consent from their parents. The sample of adolescents was constrained by limited access to the population of interest, which accounted both for its reduced size and for having adolescents carrying out both tasks.

### *Stimuli*

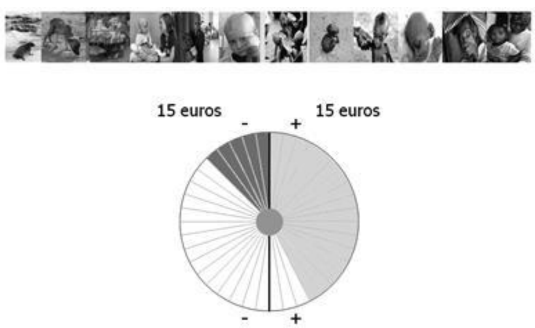
Schematic depictions of a one-roulette spinner game presented at the centre of a computer screen. In each trial, a disk was presented, divided along its vertical diameter, with the left half assigned to losses (signaled by a minus sign), and the right half to gains (plus sign). These two sectors were colored to different extents in red and green, respectively, causing the probabilities that a spinning arrow determined a loss ($P_L$) or a gain ($P_G$) to vary independently, with a complementary probability ($1 – P_L - P_G$) of a null event. Variable outcomes, either money amounts (in the hedonic task) or instrumental goods (in the utilitarian task) were associated with the loss and gain sectors, corresponding to the two non-null outcomes in each trial: value of loss ($V_L$) and value of gain ($V_G$) (Viegas et al., 2012).

The following notations are used throughout the paper: "P" for Probability and "V" for Value. "PL", "PG", "VL", and "VG" stand for Probability of Loss, Probability of Gain, Value of Loss, and Value of Gain, respectively. "G" and "L" denote Expected Gain (combinations of Probability and Value in the gain domain) and Expected Loss (combinations of Probability and Value in the loss domain). Subscript i indexes the variable levels of these factors. Italicized versions of these notations represent their subjective, psychological counterparts.

### *Design and procedure*

**Hedonic task.** In this task, 2 probabilities (0.25, 0.85) and 5 monetary values of gain and of loss (± 15, ± 150, ± 500, ± 2000, ± 7000 Euros) were factorially combined. Participants were asked to evaluate the satisfaction each particular combination would bring them if they were forced to play the resultant mixed game (games were actually never played). All subjects went through all factorial combinations. The design can thus be described, using the notations given above, as a 10 (G) × 10 (L) repeated measures overall design with a 2 (P) × 5 (V) subdesign embedded in each molar factor. The money amounts were presented as accruing to (in case of a net gain) or subtracting from (in case of a net loss) a fund for humanitarian causes, such as HIV eradication, animal protection, eradicating children's hunger, cancer treatment, etc. Each of these causes was vividly described and illustrated by an unsettling single-case photo. The whole set of photos remained visible at the top of the screen for the time each game was being presented (see Figure 1).

**Figure 1**
Illustration of a two (non-null) outcome mixed prospect with independent probabilities of loss and gain in the hedonic task



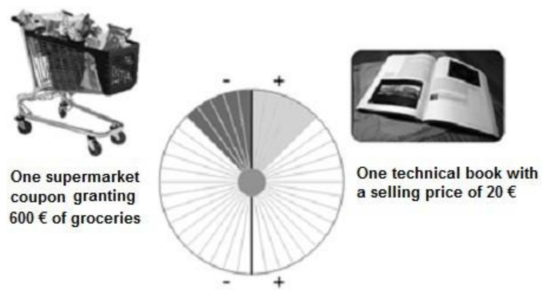

The set of distressing images associated with humanitarian causes remained visible at the top of the screen during the stimuli presentation.
Source: own work

Participants expressed their judgments on a horizontal bipolar graphic scale (left-anchored on "very unsatisfied" and right-anchored on "very satisfied") appearing at the bottom of the screen. They answered by locating a mouse cursor on the scale and clicking on a button. Their answer was automatically converted to a numerical 0-40 scale. Careful instructions and a block of 10 training trials were provided before starting the experiment proper. Performance on the task was self-paced (moving on to the next trial was prompted by an additional mouse click from the participant) .and participants were allowed by instruction to ask for a break at any point in the experiment. Feedback on the percentage of the task accomplished was provided at 50% and 75% of the trials. The average duration of the task varied between 25 and 30 minutes. There was no record of participants asking for a break.

**Utilitarian task.** The design was the same as before, but consumable instrumental goods replaced the monetary upshots. Goods were both represented by images and identified by legends (e.g., calculator, supermarket voucher). They were all priceable, and an indicative price was part of the legend (see Figure 2). Participants took on average around 30 minutes to complete the task and none of them ever asked for a break.

The option to price goods was made to ensure comparability with the monetary values used in the hedonic variant. Before starting the experiment, participants selected two out of four possible goods in each of three categories, corresponding to three distinct levels of prices. Instructed criteria for selection were the functional character of the good and the neutrality of the consumption experience (not particularly fun, exciting, or pleasurable). The two selected goods were used afterwards as instances of the given price level (defined by their mean cost). The price levels so obtained exactly matched the monetary outcomes of the hedonic task. Procedure, except for needed adaptations in the instruction phase, was the same as before.

**Figure 2**
Illustration of a two non-null outcome prospect with independent probabilities of loss and gain in the utilitarian task




Source: own work

## Results

### *Hedonic task*

**Cognitive algebra.** Graphs A and B in Figure 3 display the factorial diagrams corresponding to the G × L overall design in the hedonic condition for both adults and adolescents, with increasing marginal means of G on the abscissa (this is a standard plotting procedure in IIT/FM methodology for revealing integration fanning structures, based on the rationale that, for linear and multiplying models, marginal means afford estimates of the subjective values of the stimuli). Graphs C and D present simple moving averages calculated for each level of L over intervals of three levels of G (after ordering of marginal means), allowing a less cluttered view of the graphical trends. G1 to G5 correspond to combinations of 25% probability with the five monetary values for gain; G6 to G10, to combinations of 85% probability with those five amounts of gain. The same applies to L1 to L10, with the difference that values (equivalent in absolute terms) are now of loss. Visual inspection reveals a barrel-shaped trend (cigar-like) in the patterns, consistent with a relative ratio model of the form:

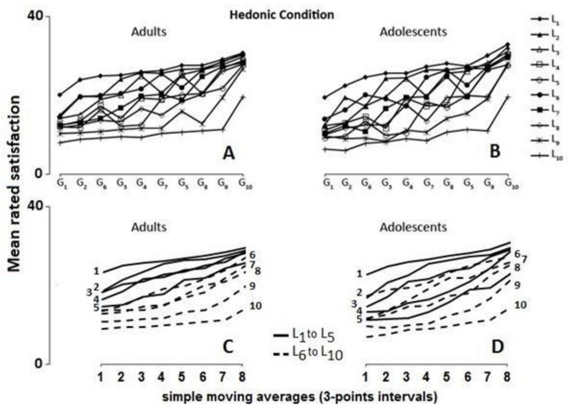
$$r = G/(G+L) \qquad (2)$$

with r standing for the psychological response, G the psychological representation of Expected Gain and L the psychological representation of Expected Loss. This corresponds to the model previously found in Viegas, Oliveira & Garriga-Trillo (2009, 2010) and Viegas, Oliveira, Garriga-Trillo, & Grieco (2012).

Statistical analysis concurred with the visual inspection. Repeated measures ANOVAs separately performed for adults and adolescents disclosed in both cases significant main effects of both factors (Adults: $F$ (9, 261) = 171.50 and $F$ (9, 261) = 184.55, main effects of G and L respectively, *ps* < 0.001; Adolescents: $F$ (9, 153) = 63.34 and $F$ (9, 153) = 92.25, *ps* < 0.001), and a significant G × L interaction ( $F$ (81, 2349) = 17.98 and $F$ (81, 1377) = 7.12, adults and adolescents respectively, *ps* < 0.001), resting mainly on the linear × quadratic ( $F$ (1, 29) = 132.97 and $F$ (1, 17) = 44.40, adults and adolescents respectively, *ps* < 0.001) and the quadratic × linear ( $F$ (1, 29) = 90.47 and $F$ (1, 17) = 51.11, adults and adolescents respectively, *ps* < 0.001) components, consistent with the signaled barrel trend. A few other interaction components also reached significance ( $p \leq 0.05$) in both groups, which as a rule presented much lower $\eta^2_p$ values than the former. These were all higher order components (e.g., linear × order 4, quadratic × order 5, order 7 × order 7 in adults; quadratic × order 5, order 4 × order 5; order 9 × order 6, in adolescents), partly reflecting the effect of the particular choice of levels in the factors (the ratio model thus not entailed that linear × quadratic and quadratic × linear contrasts associated with a barreling trend should exhaust the interaction term), partly the sensitivity of the test to accessory fluctuations in the means.

**Figure 3**

Graphs A and B: Factorial plots corresponding to the 10 (G) × 10 (L) overall design for adults and adolescents in the hedonic task




Increasing marginal means of G (Expected Gain) are used in the abscissa, and L (Expected Loss) is the curve parameter. Graphs C and D: moving averages calculated over intervals of three levels of G for each level of L. Full lines correspond to levels $L_1$ to $L_5$ (25% probability of a loss varied across five levels); dashed lines correspond to $L_6$ to $L_{10}$ (85% probability of a loss varied across the same five levels).
Source: own work

The option to alternatively redescribe the 10 (G) × 10 (L) design as a (2 ($P_G$) × 5 ($V_G$)) × (2 ($P_L$) × 5 ($V_L$)) design motivated a second round of graphical and statistical analyses, focusing on the P × V embedded designs. Linear fans were apparent for both the $P_G \times V_G$ and $P_L \times V_L$ subdesigns, suggestive of a multiplicative integration of P and V. This was statistically supported by significant interactions (Adults: $F$ (4, 116) = 33.57 and 22.51, gain and loss domains respectively, *ps* < 0.001; Adolescents: $F$ (4, 68) = 7.14 and 4.65, $p$ < 0.001 and $p$ = 0.002), concentrated moreover on their bilinear components (Adults: $F$ (1, 29) = 62.50 and 47.58, gain and loss domains respectively, *ps* < 0.001;. Adolescents: $F$ (1, 17) = 9.19 and 10.61, $p$ = 0.008 and $p$ = 0.005). The residuals left by the bilinear components were further tested with the FM program (version 2.1) included in the CALSTAT package (Weiss, 1997-2007), which provided in all cases nonsignificant F values < 1.

The relations between $V_G$ and $V_L$ were, in turn, consistent with a relative ratio operation between the values of gain and loss, showing a pronounced barrel pattern. This was supported, for both adults and adolescents, by significant interactions ( $F$ (16, 464) = 33.97 and $F$ (16, 272) = 17.43, adults and adolescents respectively, *ps* < 0.001) resting chiefly on the linear × quadratic ( $F$ (1, 29) = 78.62 and $F$ (1, 17) = 28.60, ps < 0.001) and the quadratic × linear ( $F$ (1, 29) =134.27 and $F$ (1, 17) = 57.85, *ps* < 0.001) components.

The complete algebraic structure of the model can thus be written as:

$$r = \frac{P_G V_G}{(P_G V_G + P_L V_L)} \qquad (3)$$

The linearity of the response scale, a foremost concern in the FM methodology (Anderson, 1981, 1982) is well buttressed by the multiplying rule found between P and V. Not only was this finding replicated in both the gain and the loss domains, and both with adults and adolescents, it converges with the recurrent finding of value and probability multiplication in the FM literature (e.g., Anderson & Shanteau, 1970; Anderson & Schlottmann, 1991; Shanteau, 1974, 1975; Schlottmann, 2001; Weiss, 2006).

## Functional Measurement: Derivation of curvature and loss aversion parameters.

Functional estimates of $G_i$ and $L_i$ were derived for each participant from the relative ratio model, using the Microsoft Excel Solver Tool, as described in Viegas et al. (2012). The mean Root Mean Squared Deviation (RMSD) value associated with the model fit was 0.041 in adults and 0.047 in adolescents. These functional values are on a ratio scale, as follows from the model. Functional scales for $V_G$ and $V_L$ were then derived from $G_i$ and $L_i$ via the integration models $G = V_G \times P_G$ and $L = V_L \times P_L$ . By virtue of the linear-fan theorem, (Anderson, 1981; 1982) the derived marginal means are valid estimates of $V_{Gi}$ and $V_{Li}$ . These functional values were further established at the ratio level, following the procedures set out in Masin (2004) and illustrated in Viegas et al. (2012).

Gi and Li estimates were additionally used for the computation of a Loss Aversion (LA) coefficient for each participant. These coefficients were calculated as the mean of the ratios of each Li and its corresponding Gi (see Brooks & Zank, 2005, for the conceptual definition, and Viegas et al. 2012, for the concrete procedure). LA > 1 indicates a loss-averse, LA = 1 a neutral, and LA < 1 a gain-seeking attitude (Abdellaoui et al., 2007). Finally, $V_{Gi}$ and $V_{Li}$ were plotted against the "objective" monetary values, providing psychophysical functions which were best fit by power functions in all cases. The obtained exponents fully characterized the curvature of these psychophysical functions, irrespective of differences in scale unit, thus allowing for legitimate comparisons between adults and adolescents as well as between the domains of gain and loss (meanwhile, the use made here of power functions entails no more than their acknowledged flexibility as a curve fitting device: see Anderson, 1982, pp. 341-342).

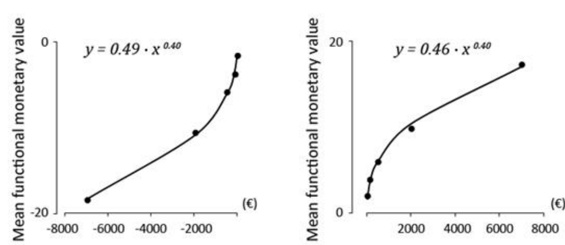
***Loss aversion.*** The mean values of LA were 1.1 and 1.2, respectively for adults and adolescents. The LA coefficient for adolescents was significantly different from the reference neutral value 1, $t$ (17) = 2.399, $p$ = 0.028. However, the difference between the two age groups was not statistically significant, $F$ (1,46) = 0.672, $p$ = 0.416.

In the adults' sample, most of the participants could be described as "loss-averse", with ≈ 73 % of individual values of LA > 1. All the remaining participants (≈ 27 %) presented values of LA < 1, qualifying thereby as "gain-seekers". Similarly, among adolescents loss-averse (LA > 1) participants amounted to 78 %, and the remaining 22 % qualified as gain-seekers. In both groups, the percentage of loss-averse participants departed significantly from 50%, $\chi^2(1, N = 30) = 6.53$, $p$ = 0.016 and $\chi^2(1, N = 18) = 5.56$, $p$ = 0.018, respectively for adults and adolescents. These percentages did not differ among the two age groups ( $p$ = 0.506, Fisher's Exact Test).

***Curvature parameters.*** Figures 4 and 5 represent the mean functional values of loss ( $V_{Li}$ : left plots) and gain ( $V_{Gi}$ : right plots) as a function of monetary values (abscissa), for adults (Figure 4) and for adolescents (Figure 5). Lines correspond to power functions, which provided the best fit for the aggregated data (by the least-squares method). The exponents indicated in the plots can thus differ somewhat from those in the text, computed as the mean of individual exponents, estimated per participant in each group. For adults, the mean exponents obtained for losses and for gains were 0.41 and 0.42, respectively. This almost complete overlap is in accordance with Prospect Theory (Tversky & Kahneman, 1992). For adolescents, the mean exponent for losses (0.40) was lower than for gains (0.46), but this was not a significant difference, $F$ (1,17) = 0.065, $p$ = 0.801. Differences between age groups were also not significant in either the domain of gains or losses, respectively $F$ (1, 46) = 1.41, $p$ = 0.24 and $F$ (1, 46) = 0.62, $p$ = 0.45.

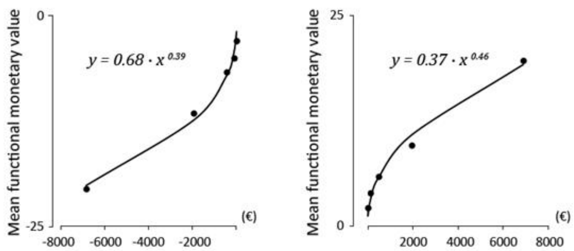
**Figure 4**

Psychophysical Value functions obtained for losses (left) and for gains (right) in the hedonic task, in the group of adults




Mean functional estimates of value are plotted against monetary outcomes. Dots represent empirical data, lines the best least-squares adjusted functions (power functions). In the equations, y represents the variable "functional monetary value" and x the variable "monetary outcome". Source: own work

**Figure 5**
Psychophysical Value functions obtained for losses (left) and for gains (right) in the hedonic task, in the group of adolescents

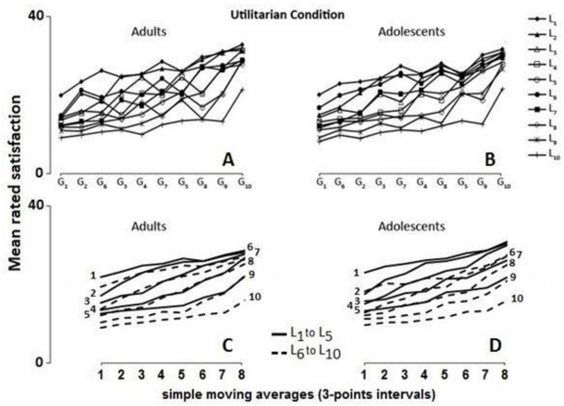



Mean functional estimates of value are plotted against monetary outcomes. Dots represent empirical data, lines the best least-squares adjusted functions (power functions). In the equations, y represents the variable “functional monetary value” and x the variable “monetary outcome”.
Source: own work

### *Utilitarian Task*

**Cognitive algebra.** The factorial G × L plots exhibited the same profile already observed in the hedonic task, corresponding to a barrel-shaped pattern (Graphs A to D in Figure 6). Consistent with the visual inspection, the same statistically significant trends disclosed in the hedonic task were replicated, for both age groups, in the repeated measurements ANOVAs conducted as well over the G × L design as over the P × V embedded subdesigns. The same compound relative ratio model described previously was thus established in both groups, allowing for the derivation of functional parameters.

**Figure 6**
Graphs A and B: Factorial plot corresponding to the 10 (G) × 10 (L) overall design for adults and adolescents in the utilitarian task




Increasing marginal means of G (Expected Gain) are used in the abscissa, and L (Expected Loss) is the curve parameter. Graphs C and D: moving averages calculated over intervals of three levels of G for each level of L. Full lines correspond to levels $L_1$ to $L_5$ (25% probability of a loss varied across five levels); dashed lines correspond to $L_6$ to $L_{10}$ (85% probability of a loss varied across the same five levels).
Source: own work

## Functional measurement: Derivation of curvature and loss aversion parameters.

Functional estimates of $G_i$ and $L_i$ were derived as before, on an individual-subject basis, using the Solver tool (Mean RMSD = 0.04 for adults and 0.045 for adolescents). LA coefficients were then computed for each participant, and functional estimates of $V_{Gi}$ and $V_{Li}$ were obtained on a ratio scale along the same lines as before.

***Loss aversion.*** Mean values of LA were 1.11 for adults and 1.07 for adolescents. One-sample t-tests performed on each group revealed a significant difference regarding the neutral value 1 for adults, $t$ (29) = 2.84, $p$ = 0.008. However, the means of the two age groups were not statistically different, $F$ (1,46) = 0.244, $p$ = 0.644.

In both groups, the percentage of loss-averse participants (77% among adults, 50% among adolescents) did not significantly depart from 50%. For the adults, the percentage of gain-seekers was now 33 % (10 out of 30), as compared to 27 % in the hedonic condition. For adolescents, it was 50 % (9 out of 18 participants), as compared to 22 % in the hedonic condition. These differences across tasks were not statistically significant in either group, $\chi^2(1, N = 60) = 0.317$, $p = 0.573$ and $\chi^2(1, N = 36) = 3.010$, $p = 0.082$. The same happened with differences in percentages between the two age groups, $\chi^2(1, N = 48) = 1.30$, $p = 0.253$.

***Curvature parameters.*** As in the previous task, loss $V_{Li}$ and gain $V_{Gi}$ were plotted as a function of monetary values, giving rise to psychophysical loss and gain functions. Power functions provided the best fit to data in all cases. Concave-shaped gain functions and convex-shaped loss curves were obtained for every participant, with only two participants in each age group approaching linearity (criterion set at $0.9 \leq \alpha \leq 1$).

For adults, the mean power exponents were 0.53 for gains and 0.42 for losses, a statistically significant difference, $F(1, 29) = 8.61$, $p = 0.006$. For adolescents, the power exponent for losses and for gains was 0.44 (i.e., the same in both domains). Differences between age groups were not significant either for gains, $F(1, 46) = 0.55$, $p = 0.46$, or for losses, $F(1, 46) = 0.07$, $p = 0.78$.

In the adults' group, the exponent for gains was higher (more linear) in the utilitarian (0.53) than in the hedonic task (0.42), $F(1,58) = 7.37$, $p = 0.009$. No other significant differences emerged between the curvature parameters estimated in the two tasks.

## General discussion

Based on the relative ratio algebraic model first established in Viegas et al. (2009) and replicated in this study in both tasks, loss aversion coefficients and curvature parameters (indexing scope-insensitivity) could be estimated, in each task, for each participant in each age group. Comparisons were then performed across age groups and tasks between the loss aversion coefficients (LA), the prevalence of loss-averse and gain-seeking participants, and the power exponents of the psychophysical functions obtained for gains and for losses.

As explained in the introduction, the dual-process concept of the value function (Hsee & Rottenstreich, 2004; Rottenstreich & Shu, 2004) predicted that both scope-insensitivity and LA values should increase in the hedonic variant of the task. As for the Reyna and Farley's (2006, 2007) proposal, it would lead to expect lower values of LA, a lower percentage of loss-averse participants, and curvature parameters closer to 1 (i.e., more linear, less scope-insensitive value functions) in the group of adolescents.

Results concerning LA can be summarized as follows (see Table 1). Mean LA coefficients presented little variation across tasks and age groups, being close to 1 in all cases ($\approx 1.1$). In the utilitarian task, the LA coefficient for adults was statistically different from 1 ($> 1$), but not for adolescents, which might be taken as favorable to Reyna and Farley's hypothesis. However, the exact opposite result was found in the hedonic task, where the LA coefficient for adolescents, but not for adults, differed significantly from 1 ($> 1$). Across groups and tasks, the difference involving the hedonic (Mean = 1.2, SD = 0.35) and the utilitarian (Mean = 1.07, SD = 0.28) tasks in the group of adolescents was the only one to be found significant, $F(1,17) = 7.440$, $p = 0.014$. This result is in line with the dual-process prediction of larger LA values in the hedonic task, but was not replicated in the adults' samples.

Differences in the percentages of loss-averse (or, equivalently, gain-seeking) participants among tasks or age groups were never significant, a result at variance with the predictions derived from Reyna and Farley's proposal. This needs qualification, however, by the reduced statistical power afforded by the adolescents' sample size in age-group comparisons. However, in the hedonic task, the percentage of loss-averse participants was statistically above 50% in both age groups, while it did not depart significantly from that reference value in the utilitarian task, a result generally consistent with the dual-processing view.

**Table 1**

*Summary of the mean estimated curvature parameters of the psychophysical value functions ($\alpha^+$ and $\alpha^-$), mean loss aversion coefficients (LA) and percentage of loss-averse (% LA) and gain-seeking (% GS) participants in each age group. Significant differences are signaled by line segments connecting pairs of numbers (means or percentages) in bold type .*

| | ADULTS | | | | | ADOLESCENTS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *α +* | *α -* | *LA* | *% LA* | *% GS* | *α +* | *α -* | *LA* | *% LA* | *% GS* |
| **Hedon.** | **0.42** | 0.41 | 1.1 | **73** | **27** | 0.46 | 0.40 | **1.2** | **78** | **22** |
| **Utilit.** | **0.53** | **0.42** | 1.1 | 63 | 33 | 0.44 | 0.44 | **1.07** | 50 | 50 |

Regarding the scope-insensitivity of value curves (indexed by power exponents below 1), two significant differences were found, both in the adults' sample: one between the curvature of the gains function in the hedonic (0.42) and the utilitarian (0.53) tasks; another between the curvature for gains (0.53) and for losses (0.42) in the utilitarian task. The direction of the first difference concurs with the prediction of less scope-insensitivity in the value function for instrumental goods (reflecting, under the dual-processing view, the increased contribution of deliberative processes); the direction of the second difference also agrees with the prediction of more scope-insensitivity in the more affectively-charged loss domain. On the other hand, the direction of the largest (yet still non-significant) observed difference between adults and adolescents, involving the curvature of the gains function in the "utilitarian condition" ($\alpha+ = 0.53$ for adults and 0.44 for adolescents), was opposite in direction to what Reyna and Farley's conjecture would lead to predict.

Overall, results did not favor the predictions derived from Reyna and Farley' (2006, 2007) developmental hypothesis, while lending a fair amount of support to the dual-processing view of the value curves (Hsee & Rottenstreich, 2004). Marked similarities between adults and adolescents were the general rule, whether one considers the qualitative morphology of the value curves, their quantitative parameters, or the mean magnitudes of LA coefficients. A tendency for a less homogeneous attitude towards loss-aversion seemed nevertheless apparent in adolescents, manifesting in a half-half split between loss-averse and gain-seeking participants in the utilitarian task. The difference regarding the corresponding frequencies in the adults' sample (63 % loss-averse versus 33% gain-seekers) was only marginally significant at best, $\chi^2(1, N = 48) = 3.010$, $p = 0.082$ ($< 0.10$). In any case, such a tendency would suggest less a more deliberative attitude in adolescents (as entailed by Reyna and Farley's proposal) than a developmental path along which risk attitudes get increasingly polarized towards loss aversion (a hypothesis requiring further work, with larger samples spanning a wider number of age levels). More generally, the occurrence, in all cases, of non-negligible proportions of gain-seeking participants underlines the role of individual differences and does not square easily with the psychophysical modeling of loss aversion as a structural (mandatory) component of the utility curve.

One limitation of the present study concerns the reduced sample sizes, particularly for the adolescents' group. This circumstance affects mostly the statistical power of between age-groups comparisons, critical for an assessment of the Reyna and Farley's proposal. While some of the unfavorable results to this proposal do not seem accountable by lack of statistical power (as they involve differences opposing in direction the ones expected), any envisioned conclusions should nonetheless be recognized as provisional (contingent on replication in larger samples, encompassing moreover a broader age range).

Another possible objection to the study concerns the type of design. Repeated measures designs are notoriously known as vulnerable to position and carry-over effects. Although such transfer effects can be minimized trough experimental procedure, this is a legitimate enough concern to require justification of the design choice. In the present context, not only the cognitive integration model for gains and losses is postulated to operate at the single-subject level, but also meets the proposed goal of characterizing each individual, as regards scope-insensitivity and loss-aversion requires the full pattern of responses of each participant. Neither a standard between-subjects design nor a nested group design (Weiss, 2014) would suit this goal (rather, it would render it unfeasible). A related concern involves the large number of experimental conditions in the main 10 × 10 factorial design. This might be thought to induce boredom (a particular form of carry-over effect, as well noted in Weiss, 2014) and superficial processing of the stimulus, potentially changing the focus of participants' evaluations. More than an issue particular to large designs, this has actually been a commonly raised objection to standard within-subjects IIT methodology (see Anderson, 1982, p. 298). A number of indications speak against that eventuality in the present case. Besides the fact that no participant used the possibility of asking for a break, and the relatively short duration of each task (below half an hour on average), the emergence of significant differences between the hedonic and utilitarian tasks in a way consistent with the dual-process view seems hardly harmonizable with routine "easy way" processing,

To end up, it deserves to be stressed that the ensemble of results presented rests on a proper solution of the measurement problems usually glossed over in establishing the shape of value functions and the computation of loss aversion. Whatever the limitations one may want to point out to the employed integration tasks (e.g., doubtful ecological value, possible shortfalls of the operationalization of hedonic and instrumental targets), that should suffice in itself as one more illustration of the potential of FM to contribute to fundamental problems of judgment and decision making.

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## Notes

* Research article.