Supporting Information

Age Differences in Risky Choice – A Meta-Analysis

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Content

Exclusion Criteria

Overall, we found 56 papers in the literature search but we further limited the analysis to those studies that met the following criteria:

1. We included studies that allowed at least one age group comparison between a younger (ca. 18-35 years) and an older group (ca. 65-88 years). We excluded Barsky, Juster, Kimball, and Shapiro (1997), Calhoun and Hutchinson (1981); Denburg, Recknor, Bechara, and Tranel (2006); Figner, Mackinlay, Wilkening, and Weber, (2009); Harbaugh, Krause, and Vesterlund (2002); Hutchinson and Clemens (1980); Hutchinson and Lilienthal (1980), and Kimball, Sahm, and Shapiro (2009) because these papers reported no extreme age group comparisons. We excluded Denburg, Cole, Hernandez, Yamada, Tranel, Bechara, and Wallace (2007) because the data was identical to the data in Denburg, Tranel, and Bechara (2005).
2. We included studies that provided a total performance measure for each age group. If the data (mean, standard deviation) was not given in the original paper in a numerical format, we contacted the authors to provide it. This was the case for Bruine de Bruin, Parker, and Fischhoff (2007a); Denburg et al., (2005); Henninger, Madden, and Huettel (2010); Lauriola and Levin (2001); MacPherson et al., (2002); Samanez-Larkin, Kuhnen, Yoo, and Knutson (2010); Samanez-Larkin, Wagner, and Knutson (2011); Wood, Busemeyer, Koling, Cox, and Davis (2005); Zamarian et al., (2010). However, if this request was not successful and no appropriate statistical test result was reported but the paper provided data in graphical format, we obtained the data by digitizing the means and standard deviations from plotted graphs with engauge software (Mitchell, 2007). This was the case for Denburg et al., (2005); Weller et al., (2010); and Mikels and Reed (2009). Data access was not possible for papers that did not provide data in graphical format. This led to the exclusion of Denburg, Tranel, Bechara, and Damasio (2001); Feldstein and Washburn (1980); Gächter, Johnson, and

Herrman (2007); Kovalchik, Camerer, Grether, Plott, and Allman (2005); Suzuki and Kume (2008); Vroom and Pahl (1971).

3. We included only papers reporting age differences on a task for which we had at least two independent samples. We excluded Kovalchik and Allman (2006), Sinha (1992) and Hosseini, Rostami, Yomogida, Takahashi, Tsukiura, and Kawashima (2010) because these were not combinable with any other studies.
4. We included studies reporting a behavioral measure of risk taking (cf. Appelt et al., 2011) which led to the exclusion of papers using self report measures, including Botwinick (1966; 1969), Chaubey (1974), Chou, Lee, and Ho (2007); Okun, Stock, and Ceurvorst, (1980), Okun, Siegler, and George (1978), Wallach and Kogan (1961), Okun and Elias (1977), and Okun and diVesta (1976).
5. We only included papers that allowed us to use a clear measure of risk taking which led to the exclusion of papers that investigated age differences in decision-making more generally, such as Nielsen, Knutson, and Carstensen (2008) and Samanez-Larkin, Gibbs, Khanna, Nielsen, Carstensen, and Knutson (2007).
6. In one of the tasks, the BIAS task, there were multiple measures of behavior reported. Three mistake types are possible in this task: risk-seeking mistakes, risk-aversion mistakes, and confusion mistakes. We only included risk-seeking mistakes here because they were the focus of the cited papers (Samanez-Larkin et al., 2010; 2011), occurred more frequently than either of the other two mistake types, and were the only mistake type to reliably show age differences across the papers.

Reference list of excluded papers

Barsky, R. B., Juster, F. T., & Shapiro, M. D. (1997). Preference parameters and behavioral heterogenity: An experimental approach in the health and retirement study. *The Quarterly Journal of Economics, 112,* 537–579.

Botwinick, J. (1966). Cautiousness in advanced age. *Journal of Gerontology*, *21*, 347–353. doi:10.1093/geronj/21.3.347

Botwinick, J. (1969). Disinclination to venture response versus cautiousness in responding: Age differences. *Journal of Genetic Psychology*, *1*, 55–62.

Calhoun, R. E., & Hutchinson, S. L. (1981). Decision-making in old age: Cautiousness and rigidity. *Aging and Human Development*, *13*, 89–98.

Chaubey, N. P. (1974). Effects of age on expectancy of success and on risk taking behavior. *Journal of Personality and Social Psychology*, *29*, 774–778. doi:10.1037/h0036178

Chou, K.-L., Lee, T. M. C., & Ho, A. H. Y. (2007). Does mood state change risk taking tendency in older adults? *Psychology and Aging*, *22*, 310–318. doi:10.1037/0882-7974.22.2.310

Denburg, N. L., Cole, C. A., Hernandez, M., Yamada, T. H., Tranel, D., Bechara, A., & Wallace, R. B. (2007). The orbitofrontal cortex, real world decision making, and normal aging. *Annals of the New York Academy of Sciences*, *1121*, 480–498. doi:10.1016/j.bbi.2008.05.010

Denburg, N. L., Recknor, E. C., Bechara, A., & Tranel, D. (2006). Psychophysiological anticipation of positive outcomes promotes advantageous decision-making in normal older persons. *International Journal of Psychophysiology*, *61*, 19–25. doi:10.1016/j.ijpsycho.2005.10.021

Denburg, N. L., Tranel, D., Bechara, A., & Damasio, A. R. (2001). Normal aging may compromise the ability to decide advantageously. *Brain and Cognition*, *47*, 156–185. doi:10.1006/brcg.2000.1277

Feldstein, J. H., & Washburn, D. E. (1980). Shift toward risk in adults at three age levels. *Experimental Aging Research,* 6, 149–157. doi:10.1080/03610738008258352

Figner, B., Mackinlay, R. J., Wilkening, F., & Weber, E. (2009). Affective and deliberative processes in risky choice: Age differences in risk taking in the Columbia Card Task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35,* 709-730. doi:10.1037/a0014983

Gächter, S., Johnson, E. J., & Herrmann, A. (2007). *Individual-level loss aversion in riskless and risky choices*. (IZA DP No. 2961). Retrieved from Institute for the Study of Labor website http://www.iza.org/de/webcontent/publications/papers/viewAbstract?dp_id=2961

Harbaugh, W. T., Krause, K., & Vesterlund, L. (2002). Risk attitudes of children and adults: Choices over small and large probability gains and losses. *Experimental Economics*, *5*, 53–84. doi:10.1023/A:1016316725855

Hosseini, S. M. H., Rostami, M., Yomogida, Y., Takahashi, M., Tsukiura, T., & Kawashima, R. (2010). Aging and decision making under uncertainty: Behavioral and neural evidence for the preservation of decision making in the absence of learning in old age. *NeuroImage, 52,* 1514–1520. doi: 10.1016/j.neuroimage.2010.05.008

Hutchison, S. L., & Clemens, F. W. (1980). Advisement to take risk: The elderly's view. *Psychological Reports*, *47*, 426. doi:10.1111/j.1756-185X.2010.01507.x

Hutchinson, S., & Lilienthal, R. (1980). Advisement to take risk: A study of attitudes toward the old. *International Journal of Behavioral Development*, *3*, 19–26. doi:10.1177/016502548000300103

Kimball, M. S., Sahm, R. C., & Shapiro, M. D. (2009). *Risk preferences in the PSID: Individual imputations and family covariation* (Working Paper Series No. 14754). Retrieved from the National Bureau of Economics Research website http://www.nber.org/papers/w14754

Kovalchik S, Allman J (2005) Measuring reversal learning: Introducing the variable Iowa Gambling Task in a study of young and old normals. *Cognition and Emotion, 20*, 714-728.

Kovalchik, S., Camerer, C. F., Grether, D. M., Plott, C. R., & Allman, J. M. (2005). Aging and decision making: A comparison between neurologically healthy elderly and young individuals. *Journal of Economic Behavior and Organization*, *58*, 79–94. doi:10.1016/j.jebo.2003.12.001

Nielsen, L., Knutson, B., & Carstensen, L. L. (2008). Affect dynamics, affective forecasting, and aging. *Emotion, 8,* 318–330. doi:10.1037/1528-3542.8.3.318

Okun, M. A. (1976). Adult age and cautiousness in decision. *Human Development, 19,* 220–233.

Okun, M. A., & Di Vesta, F. J. D. (1976). Cautiousness in adulthood as a function of age and instructions. *Journal of Gerontology*, *31*, 571–576.

Okun, M. A., & Elias, C. S. (1977). Cautiousness in adulthood as a function of age and payoff structure. *Journal of Gerontology*, *32*, 451–455.

Okun, M. A., Siegler, I. C., & George, L. K. (1978). Cautiousness and verbal learning in adulthood. *Journal of Gerontology*, *33*, 94–97.

Okun, M. A, Stock, W. A., & Ceurvorst, R. W. (1980). Risk taking through the adult life span. *Experimental Aging Research*, *6*, 463–473. doi:10.1080/03610738008258381

Samanez-Larkin, G. R., Gibbs, S. E. B., Khanna, K., Nielsen, L., Carstensen, L. L., & Knutson, B. (2007). Anticipation of monetary gain but not loss in healthy older adults. *Nature Neuroscience*, *10*, 787–791. doi:10.1038/nn1894

Sinha, T. (1992). *Are older people more risk averse?* (Discussion Papers No. 32). Retrieved from School of Business, Bond University http://epublications.bond.edu.au/discussion_papers/32

Suzuki, A., & Kume, K. (2008). *Aging, probability weighting, and reference point adaptation: An experimental study* (ISER Discussion Paper No. 720). Retrieved from Osaka University, Institute of Social and Economic Research website http://www.iser.osaka-u.ac.jp/coe/dp/pdf/no.9_dp.pdf

Wallach, M. A., & Kogan, N. (1961). Aspects of judgment and decision making: Interrelationships change with age. *Behavioral Science*, *6*, 23–36. doi:10.1002/bs.3830060104

Detailed information about included papers

Paper	Dependent variable	Data Acquisition										
		M(SD) in paper	Data provided by author	Digitized from graph	F-Statistics	t-Statistics	r-Statistics	z-Statistics	SEM to SD transformation	Performance contingent payment	Participation Compensation	Achieved Power [b]
Iowa Gambing Task												
Baena, Allen, Kaut, & Hall (2010)	Good minus bad deck choices	●									●	.34
Denburg, Tranel, & Bechara (2005)	Good minus bad deck choices			●					●		●	.34
Denburg et al. (2009)	Good minus bad deck choices					●					●	.53
Fein, McGillivray, & Finn (2007)	Good minus bad deck choices	●	●							●	●	.51
Henninger, Madden & Huettel (2010)	Good minus bad deck choices		●							●	●	.43
Isella, Mapelli, Morielli, Franceschi, & Ildebrando (2007)	Good minus bad deck choices		●						●			.34
Lamar & Resnick (2004)	Good deck choices	●										.23
MacPherson, Phillips, & Della Sala (2002)	Good minus bad deck choices	●					●				●	.28
Wood, Busemeyer, Koling, Cox, & Davis (2005)	Good minus bad deck choices				●						●	.52
Zamarian, Sinz, Bonatti, Gamboz, & Delazer (2008)	Good minus bad deck choices		●									.35
Balloon Analogue Risk Task												
Henninger, Madden & Huettel (2010)	Pumps on unpopped balloons	●								●	●	.64
Rolison, Madden, & Huettel (2010)	Pumps on unpopped balloons	●								●	●	.53

Paper	Dependent Variable	Data Acquisition										
		M(SD) in paper	Data provided by author	Digitized from graph	F-Statistics	t-Statistics	r-Statistics	z-Statistics	SEM to SD transformation	Performance contingent payment	Participation Compensation	Achieved Power [b]
Behavioral Investment Allocation Strategy												
Samanez-Larkin, Kuhnen, Yoo, & Knutson (2010)	Risk seeking mistakes		●							●	●	.64
Samanez-Larkin, Wagner, & Knutson (2011)	Risk seeking mistakes		●							●	●	.76
Risky vs. Safe Option Gambles												
Bruine de Bruin, Parker, & Fishhoff (2007)	Safe option choices		●									.07
Holliday (1988)	Risk taking score	●										.06
Kim, Goldstein, Hasher, & Zacks (2005)	Risky option choices							●			●	.07/.07
Lauriola, & Levin (2001)	Risky option choices		●									.06
Lee, Leung, Fox, Gao, & Chan (2008)	Safe option choices	●										.06
Mayhorn, Fisk, & Whittle (2002)	Risky option choices							●			●	.07
Mikels & Reed (2009)[a]	Risky option choices	●		●					●	●	●	.06
Roennlund, Karlsson, Laggnäs, Larsson, & Lindström (2005)	Risky option choices							●				.09
Sproten, Diener, Fiebach, & Schwieren (2010)	Risky option choices	●								●	●	.07
Watabene & Shibutani (2010)	Safe option choices							●				.11/.11
Weller, Levin, & Denburg (2010)	Risky option choices			●					●	●		.08
Zamarian, Sinz, Bonatti, Gamboz, & Delazer (2008)	Risky option choices	●										.07

Paper	Dependent Variable	Data Acquisition										
		M(SD) in paper	Data provided by author	Digitized from graph	F-Statistics	t-Statistics	r-Statistics	z-Statistics	SEM to SD transformation	Performance contingent payment	Participation Compensation	Achieved Power [b]
Blackjack												
Ashman, Dror, Houlette, & Levy (2003)	Cards taken in risk level							●				.07
Dror, Katona, & Mungur (1998)	Cards taken in risk level				●						●	.07
Rafaely, Dror, & Remington (2006)	Cards taken in risk level				●							.09/ .1
Cambridge Gambling Task												
Deakin, Aitken, Robbins, & Sahakian (2004)	Higher probability odd choices			•					•			.69
Henninger, Madden, & Huettel (2010)	Lower probability odd choices	●								●	●	.80

Note. [a] only means provided in the paper (SEM were digitized from bar chart). [b] Achieved power for the total performance measure summary effect. Only for Sproten et al. (2010) and Watabene and Shibutani (2010) the summary effect for the gain- respectively loss-frame was used.

Formulas for effect size calculation

1. Formula to calculate Cohen's d from means and standard deviations

   $d = (M_y - M_o) / [(n_y - 1)s_y^2 + (n_o - 1)s_o^2 / (n_y + n_o - 2)]^{1/2}$

2. Formula to calculate Cohen's d from F-statistics with one degree of freedom

   $d = [(F \cdot (n_o + n_y)] / (n_o \cdot n_y)]^{1/2}$

3. Formula to calculate Cohen's d from t-statistics

   $d = t \cdot [(n_o + n_y)/(n_o \cdot n_y)]^{1/2}$

4. Formula to calculate Cohen's d from a correlation

   $d = 2r / (1 - r^2)^{1/2}$

5. z-test between proportions (z-value is equivalent with Cohen's d)

   $p = (p_o * n_o + p_y * n_y)/(n_o + n_y)$

   $SD_p = sqrt(p*(1-p)*(1/n_o + 1/n_y))$

   $z = p_y - p_o / SD_p$

6. Formula to transform Cohen's d into Hedge's g

   $g = 1 - [3 / (4 \cdot ((n_o + n_y - 2) - 1) \cdot d]$

7. Power calculation with G-power

   - Test family = t-Test
   - Statistical Test = Differences between two independent means (two groups)
   - Type of power analysis = Post hoc: compute achieved power – given $\propto = .05$, sample size, and effect size (one-tailed)

Software

1. We used R and the rmeta package to calculate effect sizes and other statistical results:

R Development Core Team (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Lumley, T. (2009) Rmeta version 2.10. R package. Retrieved from http://cran.r-project.org

2. We used Engauge to digitize data from figures:

Mitchell, M. (2007). Engauge Digitizer (Version 4.1) [Computer software]. Retrieved 14, November, 2010. Available from: http://digitizer.sourceforge.net/

3. We used Gpower to calculate power for individual studies:

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*, 1149-1160. Available from http://www.psycho.uni-duesseldorf.de/abteilungen/aap/gpower3/download-and-register