
Comparative Rating Measures of Health and Environmental Exposures: How Well Do Twins Agree?

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Twins are sometimes used as proxy informants but little is known about reliability and validity of the information thus obtained. The present study asks: (1) to what extent do twin pairs agree with each other on comparative ratings of health, psychosocial traits, and environmental exposures?; and (2) how well do comparative ratings agree with usual self-reported information about the exposures? Using 55 monozygotic (MZ) and 71 dizygotic (DZ) same-sex pairs reared together, percentage agreement was calculated for 44 comparative ratings. Pairs agreed on average about half of the time. Agreement was higher for more discrete exposures, such as smoking, but lower for more subjective variables, such as the degree to which life is experienced as stressful. Signed rank tests were used to contrast comparative ratings to differences in self-reports. Differences between twin partners in their self-report indices, where available, were in the direction suggested by the comparative rating. Comparative ratings appear most accurate for smoking and alcohol use, and less consistent for mental health symptoms and self-rated health.

Epidemiological studies often compare one twin's self-reported behaviors and exposures to the twin partner's in order to test whether or not the exposure is related to a health outcome experienced differentially by the twin pair. Less often used is an alternative technique of comparative ratings, in which twins are asked if they or their partner had greater exposure. Comparative ratings have been used in twin studies when absolute measures may be difficult to complete retrospectively or when differential experiences are a focus of study. Additionally, only one twin is sometimes available to provide data and comparative ratings may be easier for proxy informants than trying to estimate the exact extent of an exposure. Although the comparative approach is very attractive, little has been published using this approach.

The Sibling Inventory of Differential Experiences (SIDE) was one of the first comparative measures used among siblings (Baker & Daniels, 1990; Daniels &

Plomin, 1985) to examine sibling interaction, parental treatment and peer characteristics. Agreement among adult twins with respect to differences in parental treatment and peer group characteristics was moderate while agreement regarding sibling interaction was poorer, particularly for twins who were 35 years and older (Baker & Daniels, 1990).

Thomas Mack has established a comparative approach for risk factors for breast cancers and multiple sclerosis. As yet unpublished findings suggest that twin agreement is higher for objective (e.g., age at menarche, breast cancer) than for subjective (e.g., who had greater success) or depreciatory comparisons (e.g., who had more trouble in school; T. Mack, personal communication, March, 2000). Finally, the utility and reliability of twin comparative ratings has been examined in a study on mosquito bites in adolescent twins (Kirk et al., 2000). Findings indicated that perceived twin differences in mosquito bite frequency ('Compared with your twin who is bitten by mosquitoes more often?') were related to differences between one twin's self-report and the twin partner's self-report in the expected direction, suggesting that the comparative rating was valid.

Relevant published findings on the use of proxy information in a noncomparative format in a case-control twin study of breast cancer (Hamilton & Mack, 2000) indicate good to excellent reliability between proxy and self-reports for several breast cancer risk factors (e.g., ages at menarche and menopause, oral contraceptive use, smoking), with kappa statistics ranging from .60 to 1.0. Similarly, co-twins have also been used as proxy informants for smoking during pregnancy (Heath et al., 2003). Generally good agreement between twins' retrospective reports of smoking during pregnancy was

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observed in over 821 pregnancies (e.g., over 95% agreement for *never smoked regularly*). However, pair discrepancies did occur in nearly 11% of twins with a history of smoking, and were interpreted as cases of underreporting by the target twin. Such findings indicate that we could expect good agreement for twins' comparative ratings of health factors.

The purpose of the present study was to examine (1) how well monozygotic (MZ) and dizygotic (DZ) twin pairs agree on comparative ratings relating to putative dementia risk factors; and (2) how well comparative ratings agree with independent self-reported information about the exposures.

Methods

Participants

Participants were selected from the third wave of in-person testing (IPT3) from the Swedish Adoption/Twin Study of Aging (Pedersen et al., 1991). The current analyses included 52 MZ and 75 same-sex DZ twin pairs reared together who both participated in IPT3. One-hundred-and-forty individuals were female and 114 were male. The age range was between 40 and 77 years with a mean age of 59.6 years.

Measures

Twins were asked to complete a 44-item questionnaire (see appendix), indicating for each item whether they or their twin partner engaged in a particular behavior to a greater extent, had greater exposure to variety of environmental agents, or were in better or worse physical and psychological health. Responses of *don't know* were set to *missing*. Nonresponse plus endorsement of *don't know* accounted for between 3.94% (which twin born first) and 47.14% (age at menopause) of responses across items. Furthermore, *neither, equally or about the same* were recoded into a single category.

In this and prior waves of data collection, there were survey questions asking for self-reports of various exposures and health conditions. The corresponding variables included: (a) use of cigarettes and alcohol; (b) occupational and hobby exposures, such as livestock slaughter or dressing wild game (including whether the contact occurred as a youth or adult, and whether it had occurred in the last three years or in multiple time periods); (c) physical and psychological health such as self-reported health, number of illnesses, depressive symptoms (Center for Epidemiologic Studies — Depression total score; Radloff, 1977) and number of life events (Holmes & Rahe, 1967; Persson, 1980). In total there were 11 self-report indicators that could be examined in the validity analyses of the comparative ratings (with 2 self-report indicators for smoking, alcohol use and stressful life events). For validity comparisons difference scores were created in the twins' self-reports according to which twin was agreed upon to have higher alcohol or tobacco consumption, participated more in handling livestock or game hunting, or

had worse physical or mental health. Next, the pair difference scores were compared to type and level of agreement on the comparative measure. Each twin pair's level of agreement on each item was coded as follows: (1) twins who agreed that they differed were expected to show the largest pair differences and were coded as 1; (2) those pairs who responded either with *don't know* or were nonresponders were coded as .5; (3) those pairs who disagreed across any response categories were coded as $-.5$; and (4) those endorsing *neither* or *equally as much* were expected to show the smallest differences and were coded as -1 .

Results

Agreement Between Twins in a Pair

MZ and DZ twins were compared with respect to their agreement as to which twin was more exposed to a particular element or experienced with a greater frequency a specific physical or mental health symptom. Table 1 shows for each comparative rating how many pairs provided complete data and how well pairs agreed. Kappa statistics were calculated using SAS 8.1 (SAS, 1999) both within each zygosity group and overall. In order to estimate the kappa statistic in SAS Proc Freq, it was necessary to ensure square cross-tabulation tables for analysis as not all response categories were endorsed for all items across pairs. Thus, we followed the procedure of Crewsen (2001) where dummy observations are created but do not enter the computation of the kappa statistics. An equality test indicates whether there are differences in agreement by zygosity. Results of the equality tests showed that kappa statistics did not differ significantly by zygosity except for item 1 — worse health prior to age 20 — where MZ pairs agreed more than DZ pairs. MZ pairs retained larger kappa statistics than DZ pairs for 19 of 44 items, while DZ pairs exhibited higher kappa statistics for 22 of 44 items. The average overall kappa was .40. Agreement was highest for overt exposures or traits, such as weight (kappa = .68), smoking/drinking (kappa = .64 to .77) and wild game exposure (kappa = .61). More subjective or concealed traits such as headache frequency (kappa = .48), stress (kappa = .33) and finding one's way in unfamiliar places (kappa = .25) often showed considerably less agreement between twins. There was a pattern of greater agreement for more recent exposures than earlier exposures: (a) worse health prior to the age of 20 years (kappa = .31) is nearly the same as for worse health between 20 to 40 years (kappa = .27), but both were lower than worse health after the age of 40 years (kappa = .45); (b) agreement was lower for total number of operations with anesthesia (kappa = .27) compared to the last 3 years (kappa = .40) but with overlapping confidence intervals.

In comparing kappa statistics across items, the underlying assumption that proportions for each response category are the same (i.e., similar proportions endorse *me, my twin*, and *equally as much/neither*) may

Table 1
Twin Pair Agreement Across Zygosity

Category	Qitem	Item description	N		Kappa		Equality test		Overall Kappa	Confidence Interval	
			MZ	DZ	MZ	DZ	χ^2 (1)	<i>p</i>		L	U
General	35	Born first	51	69	.83	.83	0.00	1.00	.83	.71	.95
Education	11	Better grades	45	64	.61	.56	0.09	.77	.58	.44	.72
	13	Read more books before age 20	33	46	.43	.60	0.92	.34	.54	.38	.70
Psychological	12	Find way in unfamiliar places	37	51	.18	.31	0.72	.40	.25	.10	.41
	42	More serious depression	27	38	.66	.54	0.49	.48	.60	.43	.77
	31	Dealt better stressful situations	29	31	.41	.18	1.34	.25	.29	.10	.48
	30	More stress	33	47	.29	.36	0.14	.70	.33	.17	.49
Health	1	Worse health before age 20	37	59	.55	.16	6.49	.01	.31	.16	.45
	2	Worse health, age 20–40 years	39	56	.21	.31	0.39	.53	.27	.12	.42
	3	Worse health, after age 40	43	54	.47	.44	0.06	.81	.45	.31	.59
	41	Allergies	42	55	.35	.41	0.09	.76	.39	.19	.59
	37	Asthma	38	50	.22	.37	0.45	.50	.32	.11	.52
	36	Weight	28	42	.57	.75	1.17	.28	.68	.53	.84
	43	Age of menarche	13	18	.40	.63	1.25	.26	.51	.30	.71
Head/brain	44	Age of menopause	16	9	.38	.50	0.26	.61	.43	.19	.67
	32	Participation in contact sports	46	64	.43	.54	0.38	.54	.50	.33	.66
	10	Fainted more	32	37	.01	.06	0.09	.76	.03	–.15	.22
	39	Headaches more often	22	31	.50	.46	0.05	.83	.48	.28	.67
	40	Headaches worse	21	31	.55	.46	0.20	.65	.50	.30	.69
	8	More head injuries	47	58	.21	.22	0.00	.96	.21	.04	.39
Diet exposures	9	Worse concussion	47	62	.39	.43	0.05	.83	.41	.20	.63
	7	Alcoholic beverages	41	53	.49	.70	1.93	.16	.64	.49	.78
	29	Antacids	35	34	.18	.34	0.71	.40	.27	.09	.45
	22	Baking powder	36	52	.28	.14	0.69	.41	.19	.04	.34
	19	Beef tartar	27	38	.58	.22	2.17	.14	.37	.13	.61
	21	Brains — calves/sheep	43	47	–.02	.00	0.00	—	–.02	–.06	.01
	20	Raw meat, e.g., carpaccio	29	35	.44	.25	0.45	.50	.32	.06	.58
	18	Freshwater fish	38	39	.48	.38	0.33	.56	.42	.24	.60
	16	Pickled herring or salmon	35	39	.28	.05	1.85	.17	.15	–.02	.32
	15	Raw seafood	34	47	.44	.39	0.06	.80	.41	.20	.61
Environmental exposures	17	Surströmming	45	60	.28	.34	0.12	.73	.32	.16	.48
	6	Smoked most	48	66	.85	.68	2.40	.12	.77	.67	.88
	37	Cold sores	26	43	.22	.34	0.21	.64	.30	.07	.54
	4	Operations, anesthesia	49	61	.33	.22	0.79	.37	.27	.14	.40
Work/hobby exposures	5	Operations, anesthesia — last 3 years	48	60	.39	.40	0.00	.95	.40	.23	.57
	33	X-rays/CT scans/radiation	32	36	.17	.24	0.17	.68	.20	.03	.37
	34	Carbon monoxide	23	35	.35	.40	0.05	.82	.38	.15	.61
	23	Hunting/dress game	46	60	.61	.61	0.00	1.00	.61	.45	.77
	25	Farming	47	67	.76	.51	3.28	.07	.64	.50	.78
	24	Gardening	46	63	.38	.29	0.44	.51	.33	.19	.47
	26	Lived in rural area	47	65	.61	.60	0.00	.95	.60	.48	.73
	28	Metals	45	59	.39	.48	0.18	.68	.44	.25	.64
	14	Slaughter livestock	46	62	.55	.54	0.00	.96	.54	.39	.69
	27	Solvents	40	53	.24	.38	0.59	.44	.33	.16	.50

Note: Questionnaire items (Qitem) correspond to the appendix.

The dash indicates that the *p* value was not computable for that item with degrees of freedom equal to 0.

be untenable. Examining this assumption revealed several response patterns. First, twins reported being the same for many of the traits/exposures. The median percentage agreement of sameness (response of *equally as much* or *neither*) for MZ and DZ pairs is 58% and 41% respectively, but ranges widely across traits (MZ range 0% to 93%; DZ range 0% to 94%). The median percentage of twin pairs who disagreed whether they were the same was 19% and 26% for MZ and DZ

pairs respectively (MZ range 0 to 42%; DZ range 0 to 52%). Second, there was a small tendency toward self-endorsement such that twins chose *me* over *my twin* a median of 56% of the time when ignoring endorsement of *equally as much* or *neither* (range 34% to 79%). Chi-square tests of significance, ignoring twin-pair status, indicated that 12 out of 44 items deviated significantly from equal endorsement of *me* versus *my twin*, of which 10 items showed a bias toward self-endorse-

Table 2

Contrasting Comparative Ratings to Differences in Twin Self-Reports: Pairs who Agreed to a Differential Exposure on Comparative Rating

Traits	<i>N</i> pairs	Pairs' self-report consistent with comparative report	Pairs' self-report inconsistent with comparative report	Pairs not different on self-report	Signed rank (<i>S</i>) ^a	1-tailed <i>p</i>
Dress wild game ^a	23	13	0	10	45.5	.00
Livestock slaughter ^a	27	14	4	9	45.5	.02
Self-report health ^{c,e}	43	23	11	9	-102.5	.04
Total illnesses ^c	41	21	11	9	101.5	.03
Smoke years ^b	41	35	6	0	371.0	.00
Pack years ^b	21	17	4	0	91.5	.00
Grams alcohol ^b	22	16	4	2	89.0	.00
Frequency alcohol ^b	22	14	3	5	56.0	.00
Depressive symptoms ^{c,d}	22	13	7	2	51.0	.03
Life events total ^c	25	10	14	1	-10.0	.39
Uncontrollable life events ^c	25	5	10	10	-21.5	.12

Note: ^a Self-reports from concurrent in-person testing wave (IPT3).

^b Self-reports from prior SATSA questionnaire wave (Q1).

^c Self-reports from prior SATSA questionnaire wave (Q2).

^d The pair differences scores exceeded a skewness of 1. To maintain the appropriateness of the signed rank test, the upper and lower tail values of the difference distribution were winsorized to 90th and 10th percentiles, respectively.

^e The self-report score for the 'healthier' or 'unexposed' twin was subtracted from the self-report score for the 'sicker' or 'exposed' twin. Thus, the sign rank test is expected to be positive for all self-report variables except for self-report health where higher scores indicate better health.

ment (e.g., 'Who had more operations using anesthesia?'; 'Who had the worst concussion?'; 'Who had more stress in his or her life?'; 'Which of you had the earlier age of menopause?') while only two items showed a significant preponderance of choosing the co-twin over one's self: 'Just in the past three years, who had worse physical health?', and 'Which of you has had more serious times of feeling depressed?'

Agreement Between Comparative and Self-Report Information

Table 2 presents results comparing twins' self-reports to comparative ratings for pairs agreeing that one twin was higher than the other (i.e., pairs were consistent in choosing one member as having greater exposure). Signed rank tests, calculated using the SAS univariate procedure (SAS, 1999), were used to contrast comparative ratings to differences between one twin's self-report and the twin partner's self-report on the corresponding variable. The validity of comparative ratings was quite good, as indicated by significant signed rank test results. The response differences were in the direction that was to be expected: twins who were rated by both themselves and their co-twin as experiencing more exposure or higher incidence of physical and mental health variables, also had greater self-report values for these measures. Signed rank tests were significant for all variables with the exception of 'Life Events' ($p = .39$) and 'Uncontrollable Life Events' ($p = .12$).

Responses from twins where only one had provided a comparative rating (limited to endorsing *me* or *my*

twin) but both twins had supplied self-report were also examined. The number of pairs for each trait ranged from 0 (dress wild game, livestock slaughter) to 17 (depressive symptoms and uncontrollable life events). The traits on which agreement between comparative rating and self-report responses was highest were the two smoking variables (where agreement was perfect but data were only available for four pairs), followed by the two alcohol variables (where level of agreement was similar to Table 2). Agreement for depressive symptoms and uncontrollable life events was quite poor with trends in the opposing direction: a greater number of pairs with self-report differences inconsistent than consistent with the comparative report.

To examine the question of validity among all available pairs, the relationships between absolute pair differences in self-report measures with level of pair agreement were examined based upon a pair's joint response to comparative ratings and coded as -1, -.5, .5 and 1, as described above. Spearman correlation coefficients served as effect size estimates between level of agreement and absolute pair differences in self-report variables tapping a relevant exposure (see Table 3). A positive correlation suggests that greater pair differences on self-report traits are associated with level of agreement regarding twin dissimilarity. Spearman correlations ranged from -.07 to .81 with a median correlation of .27. Similar to the focused look at pairs who agree that they differed, the strength of the association between pair differences and level of agreement across all comparative response categories was notably higher for substance use or hobbies than

Table 3

Spearman Correlations Between Level of Agreement on Comparative Ratings and Pair Differences in Self-Report

Trait	r_{SP}	<i>N</i> pairs
Dress wild game ^a	.23	61
Livestock slaughter ^a	.30	79
Self-report health ^c	.14	107
Total illnesses ^c	.14	103
Smoke years ^b	.81	117
Pack years ^b	.78	97
Grams alcohol ^b	.32	116
Frequency alcohol ^b	.36	118
Depressive symptoms ^c	.17	110
Life events total ^c	.06	98
Uncontrollable life events ^c	-.07	99

Note: ^a Self-reports from concurrent in-person testing wave (IPT3).^b Self-reports from prior SATSA questionnaire wave (Q1).^c Self-reports from prior SATSA questionnaire wave (Q2).

for less observable traits. By zygosity, the median Spearman correlations were .21 and .26 for MZ and DZ pairs, respectively. The relatively smaller correlations for MZ pairs may reflect a greater likelihood for MZ pairs to disagree than DZ pairs due to smaller pair differences.

Discussion

Comparative ratings of risk factors are sometimes used in twin studies, particularly when only one twin might be available to provide information, for example, if the other twin is ill or demented. The present study addressed the reliability and validity of such ratings. Results suggested that comparative ratings of risk factors are useful for observable and objective behaviors, though some caution is warranted for subjective internal states. However, where twins do agree that exposure or experiential differences exist there is a high validity with self-reports.

Our findings on the validity of comparative ratings relative to self-report data converge with direct tests of the validity of proxy responses by co-twins for smoking during pregnancy (Heath et al., 2003), as well general smoking traits (Hamilton & Mack, 2000). Kappa statistics are lower for ages at menarche and menopause than those reported by Hamilton & Mack (2000), but were very similar for amount smoked.

Some caution is warranted in relying on proxy responders for potentially derogatory traits (i.e., drinking problems, depression) as twins may show a tendency to promote their co-twin as having greater problems. The bias to report the co-twin as having more trouble with depression may have played some role in the results for singletons, for example, where only 2 of the 17 singletons reported that they had more trouble with depression than their co-twin.

These analyses represent an extension of the comparative rating methodology to older cognitively intact individuals. In this older sample we find that there is generally better agreement for more recent exposures than earlier exposures (e.g., worse health in past three years versus worse health earlier in life). Given a closer proximity in time for early life events, younger individuals may show better agreement.

In conclusion, comparative ratings can be used for objective attributes: twins do agree. Moreover, there appears to be no appreciable bias by zygosity. MZ and DZ twins do not significantly differ in agreement and only small differences were apparent in validity analyses. However, the overall level of agreement is less than desirable, especially for more subjective traits. Furthermore, the most used response choice is *don't know*. Finally, twins often say they are the same. Future studies ought to consider differing rating scale formats with more choices to examine whether such response tendencies could be altered and the comparative approach made more useful.

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APPENDIX

Questionnaire Items

Please answer the following, indicating for each item whether you or your twin partner engaged in the behavior to a greater extent or had more difficulty in some particular regard. As much as possible, avoid *don't know* and *equally as much* responses. *Neither* means that neither you nor your twin partner experienced the event.

1. As a child and youth, who had worse physical health?¹
2. As an adult, up until the past 3 years, who had worse physical health?¹
3. Just in the past three years, who had worse physical health?¹
4. Who had more operations using anaesthesia?^{II}
5. Just in the past three years, who had more operations using anaesthesia?^{II}
6. Since age 20, who smoked most?^{II}
7. Since age 20, who consumed a greater amount of alcohol?^{II}
8. Who experienced more head injuries?^{II}
9. Who had the worst concussion?^{II}
10. Who fainted more?^{II}
11. Who had better grades in school?^{III}
12. Whose ability to find their way in unfamiliar surroundings is better?^{III}
13. Before age 20, who read more books or read more frequently?^{II}
14. Who had more contact with slaughtering livestock (horses, cows, sheep, pigs)?^{II}
Who ate more of the following:^{II}
 15. raw seafood (e.g., raw oysters, clams, sushi, ceviche)?
 16. gravad or rimmad lax or pickled herring?
 17. surströmming?
 18. inland lake fish?
19. Who ate more beef tartar?^{II}
20. Who ate more gravad oxfile or carpaccio?^{II}
21. Who ate more brains (e.g., from calves or sheep)?^{II}
22. Who ate more cookies or cakes or anything baked with baking powder?^{II}
23. Who dressed more game from hunting?^{II}
24. Who spent more time gardening?^{II}
25. Who spent more time farming?^{II}
26. Who lived for a longer time in a rural area?^{II}
27. Who was exposed more to solvents, vapors, plastics, styrene, and paints at work or in hobbies?^{II}
28. Who was exposed to more metals in the form of powder or fumes at work or in hobbies, for example, welding, smelting, grinding aluminum, manganese, lead?^{II}
29. Who used more antacids?^{II}
30. Who had more stress in his or her life?^{II}
31. Who dealt better with stressful situations?^{II}
32. Who was more active in more contact sports?^{II}
33. Which of you received more x-rays, CT scans, or radiation treatment to your head, neck, or mouth?^{II}
34. Which of you was exposed more to carbon monoxide in your activities?^{II}
35. Which of you was born first?^{IV}
36. Which of you weighed more at birth?¹
37. Which of you had worse mouth sores, cold sores, or lip blisters?^V
38. Which of you had worse hayfever or asthma?^V
39. Which of you has had headaches more often?^V
40. Which of you had them worse?^V

- 41. Which of you has had worse allergies (e.g., allergic reactions or skin rashes due to food, drugs, any kind of vaccination or injection)?^v
- 42. Which of you has had more serious times of feeling depressed?^v
- 43. Which of you had the earlier age of menarche?^v
- 44. Which of you had the earlier age of menopause?^v

Response Scales:

^I	ME ()	MY TWIN ()	equally as much ()	don't know ()	
^{II}	ME ()	MY TWIN ()	equally as much ()	neither ()	don't know ()
^{III}	ME ()	MY TWIN ()	equally as much ()	don't know ()	
^{IV}	ME ()	MY TWIN ()	don't know ()		
^V	ME ()	MY TWIN ()	about the same ()	don't know ()	

