In a state of superposition: exploring (in)effective public communication about quantum technology

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Appendix

A1 Appendix I

A1.1 Reasons for deleting transcripts in step 4 of the data collection

See Table A1.

A1.2 Low Krippendorff's α in Phase 2 for codes with low prevalence

In Phase 2 of the coding scheme, Krippendorff's α remained low for some of the codes while they achieved high percent agreements. Table A3 shows the number of times those codes appeared in talks (which we think might have been detrimental for α) together with the corresponding percentage agreement and α.

Table A3

The intercoder reliability for codes with a low prevalence in Phase 2.

Code in Phase 2	Percent agreement	$\alpha < .667$	Number of times coded in 15% of data after discussion (76 transcripts)
Laser	93%	0.63	4
Smartphone	84%	0.25	3
Computer	80%	0.40	6
Quantum sensor	96%	-0.13	1
Social progress	82%	0.38	6
Economic development / competitiveness	91%	0.32	4
Risk frame	91%	0.41	4
Contextuality explanation	92%	0.66	12

Table A1

Reasons for deleting transcripts in step 4 of the data collection.

Reasons for deleting a transcript in step 4	Example	Automatically transcribed	Manually transcribed
1. Used the keyword to metaphorically denote a sudden change or step forward	“quantum leap” “that was a quantum step up from zero”	69	12
2. Mentioned the keyword in a list of other types of sciences, technologies or other terms without any further mention of it	“But if I make a list – ok, chemtrails is a bit more extreme – zodiac signs, let’s see, tarot cards, quantum-psycho. . . ”	101	28
3. One or multiple persons or institutes are involved in or know about quantum science, but there is no mention of the keyword any further	"Quantum physicist Max Planck has said, ‘When you change the way you look at things, the things you look at change.’”	48	15
4. The speaker clarifies that s/he is not using/talking/going to talk about quantum science	“I just finished my PhD in September on the quantum photophysics of organic solar cells. That’s not what my talk is on, so don’t worry.” "I don’t mean that in the quantum mechanical sense of the term of parallel universe"	24	4
5. Mentioned the keyword to indicate something’s superiority / significance or a quantity of something	"One zettabyte is equal in to all the video titles on netflix x 470 million times. This is the quantum of data."	18	1
6. Using keyword to indicate that a topic is very difficult	"Then stop spending that much, save a little and buy yourself that new rifle. It’s not quantum physics!”	6	2
7. Due to another reason, which we indicated in our annotations	E.g. making a side joke: “You, as a non-quantum observer, (Laughter), can see this band...”	108	14

A1.3 The origins of the TEDx talks in our dataset

The TEDx talks have been presented at events that were held in 55 different countries. Figure A1 shows the percentage of TEDx talks per continent and Table A5 presents the top 10 countries that appear in our dataset most often.

Figure A1

The percentage of TEDx talks in our dataset for each continent.

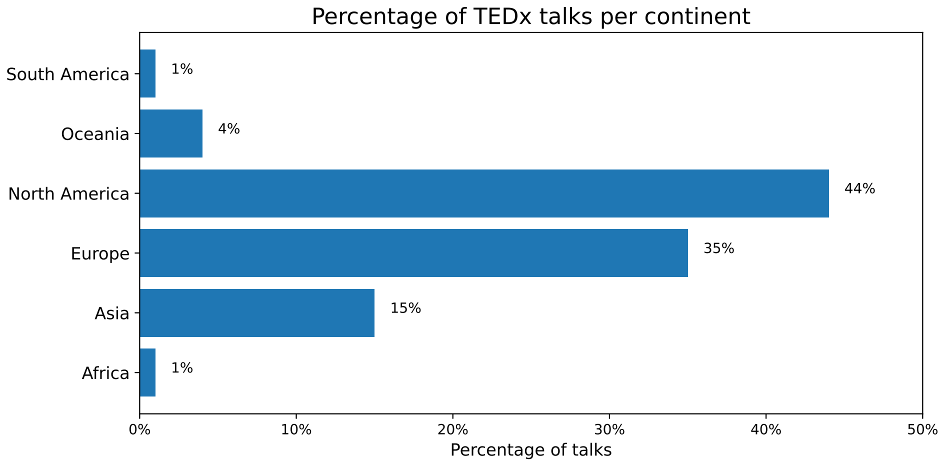


Table A5

Number of TEDx talks per country.

Country	Number of TEDx talks
United States	181
United Kingdom	46
Canada	37
India	37
Australia	20
Netherlands	18
Belgium	14
Germany	13
Italy	11
France	9

A1.4 Comparison between experts and non-experts

Figure A2

The benefits and risk frame for specific fields. These fields are based on Stichting Quantumdelta NL (2020) prediction of fields that will benefit from quantum 2.0 technology.

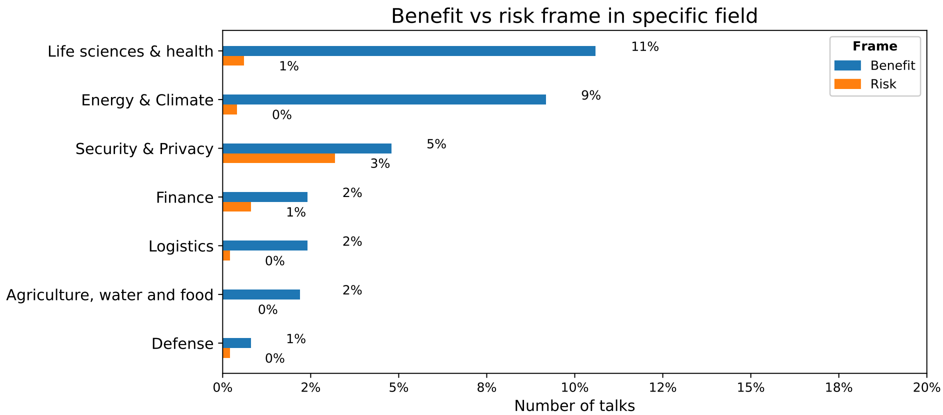
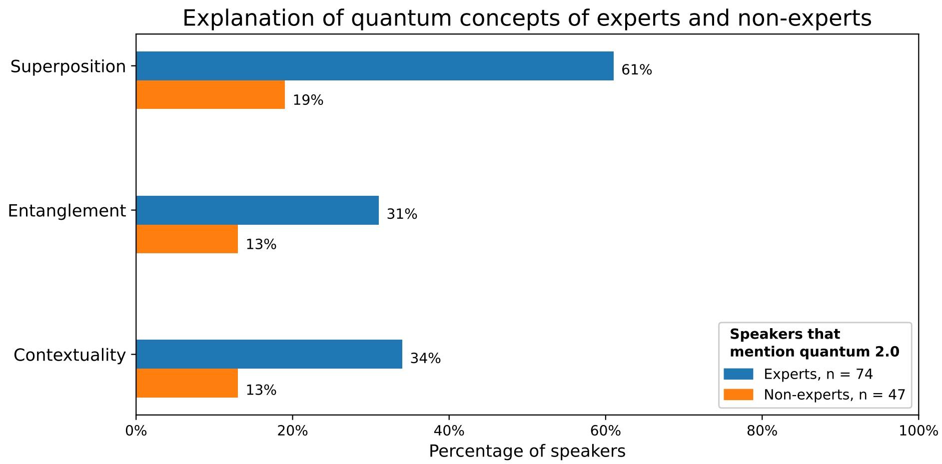


Figure A3

The percentage of speakers per expertise group that provide an explanation of an underlying quantum phenomenon when mentioning quantum 2.0 technology.



A1.5 The complete coding scheme

The complete coding scheme for Chapter 2 is presented in this section.
The complete coding scheme for Chapter 3 is very similar, but there are some differences in, for example, the identification part. It can be accessed via *this link*.

1. Identification

1. Who is coding?
   1 = Coder A, 2 = Coder B
2. What is the video ID of the TEDx talk?
3. What is the title of the TEDx talk?
   If no title is given, insert 0.
4. In what year was the TEDx talk published on the TEDx YouTube Channel?
5. What is the name of the TEDx event?
6. Is the transcription automatically generated?
   0 = no, 1 = yes
7. Is the TEDx talk flagged in the TEDx talk description? This means that it falls outside TEDx's curatorial guidelines.
   0 = no, 1 = yes

2. Speaker identification

8. What is the number of speakers in the TEDx talk?
   If there are 2 speakers, code 9 and 10 for each speaker separately.
9. What is the name of the speaker?
10. What is the quantum expertise and current profession of the speaker as provided in the YouTube description?

    Quantum experts are scientists (undergraduates and graduates excluded) and leaders (e.g. a founder, director, CEO, chairman, chief, etc.) at a university, institute, research initiative, start-up, or another organization working in or having worked in the field of quantum nanotechnology or another field in which quantum science plays a role. These include:

    - *Examples of fields in quantum nanotechnology: quantum technology, quantum information processing, quantum computational processing, nanotechnology*

- *Other examples of fields in which quantum science plays a role: quantum mechanics, quantum field theory, string theory, quantum optics, quantum cosmology (incl Big Bang theory and the black hole information paradox), quantum gravity, particle physics, high energy physics, photonics, condensed matter physics, nuclear physics, post-quantum cryptography*

If someone is described as a quantum expert: code 1 or 2.
If the quantum expertise is undefined, code 10.
If someone has no quantum expertise and multiple current professions apply: choose the first profession in the list or if other: code 11.

1 = quantum expert currently working at a university/research institute/(inter)national research organisation

Exclude (under)graduate students (=11). E.g. of an international research organisation: CERN, TNO.

2 = quantum expert currently working at a company or other/unknown

If other/unknown: specify the other/unknown in the 'comment' column. E.g. of other/unknown: a retired quantum expert, or a quantum physicist working at the EU Quantum Flagship (=international initiative).

3 = academic / leader at a university/research institute/(inter)national research organisation, main expertise domain lies outside quantum science.

Exclude (under)graduate students (=11), exclude leaders of spiritual institutes (=7)

4 = (executive) manager / leader at a company

Exclude quantum experts (=2), exclude founders of research institutes (=1 or 3) or other initiatives (=2, 7 or 11), like leaders of spiritual institutes (=7))

5 = high school teacher

Exclude university lecturers (=3)

6 = traditional medical health specialist working in health care

E.g. a surgeon, psychologist, psychiatrist

7 = alternative medical health specialist working in a holistic medical field or in a spiritual centre

E.g. a holistic doctor, sound therapist, founder of a spiritual centre

8 = high school student

9 = artist currently working in performing arts (e.g. musician) or in design (e.g. designer, architect)

Include artists that bridge quantum science and arts with each another.

10 = (quantum expertise) unknown

No information on the speaker is given or the quantum expertise is undefined. The latter means that the speaker works in a 'broad' field that includes both classical and quantum science and the specific research is not specified, e.g. 'a professor in physics' without a specification of the research s/he works on.
Examples of 'broad' fields are astrophysics, physics, cosmology - incl dark energy and black holes-, biology, chemistry.
When the current profession is known: include in comment section.

11 = other, namely...

E.g. an undergraduate or graduate student, a monk, an officer
Also code 11 if the profession only partly fits one of the non-quantum expert categories above, e.g. a biomedical engineer but it is unclear whether s/he works at a university or in a company.
If someone has multiple professions: choose the first one you come across in the talk.

3. Focus of the TEDx talks

11. Is a main topic of the TEDx talk 'quantum'?
0 = no
1 = yes, on quantum nanotechnology

The talk focusses on quantum science applications such as nanotechnology, quantum technology 1.0 (technology based on quantum transport) or quantum technology 2.0 (manipulating and reading out single quantum states, falls into one of the application domains: quantum computing & simulation, quantum communication, and quantum sensing & metrology).

2 = yes, on quantum science or a topic in which quantum science plays a role (exclude quantum nanotechnology)

The talk is about pure quantum science, or a topic in which quantum science plays a role. Examples are a talk on quantum mechanics, quantum field theory, string theory, quantum optics, quantum cosmology (incl Big Bang theory and the black hole information paradox), quantum gravity, particle physics, high energy physics, photonics, condensed matter physics, nuclear physics, post-quantum cryptography.

12. Does the TEDx talk include a holistic viewpoint?

    An example of a holistic viewpoint is when a speaker mentions that quantum mechanics tells us that everything is interconnected, for example that an illness in one causes an illness in others too.

    0 = no, 1 = yes

13. Is a quantum technology 2.0 indicator present in the transcript?

    Quantum technology 2.0 indicators include the term 'quantum' and belong to one of the following application domains: quantum computing & simulation, quantum communication, and/or quantum sensing & metrology.

    Examples: quantum technology, quantum computer, quantum algorithm.

    0 = no, 1 = yes

14. If a quantum technology 2.0 indicator is present (13 is 1=yes), quote the quantum technology 2.0 indicator. If multiple quantum technology indicators are present, only quote the first one.

Researching quantum science applications, frames and explanations

15. Is there at least one technology application of quantum science present in the transcript?

    Include: quantum technologies 1.0 (applications based on quantum physics such as the laser or smartphones), quantum technologies 2.0 (applications such as quantum computers and quantum networks), as well as other nanotechnologies (other applications in the nanometer-size range such as nanotubes).

    Do not include: when the transcript includes classical technologies based on quantum physics (i.e. quantum technologies 1.0), but the link with quantum physics is absent in the transcript.

    0 = no, 1 = yes

16. Quantum science applications: which technology application(s) of quantum science is/are mentioned?

    For each technology, indicate whether it is mentioned (0 = no, 1 = yes). Codes 1 to 5 are examples of quantum technology 1.0 and codes 6 to 8 of quantum technology 2.0.

    1 = Laser

    2 = MRI scanner

3 = Smartphone
4 = Computer
5 = Nuclear energy
6 = Quantum computer or quantum simulator
7 = Quantum network, quantum internet, quantum cryptography
8 = Quantum sensor
9 = Other / category unsure

Quantum science frames

17. Is the frame 'Quantum science (applications) is (are) spooky or enigmatic' present?

    Include: when a synonym of spooky or enigmatic refers to quantum science, a quantum science principle or a quantum science application. E.g.: quantum entanglement, quantum tunneling, string theory, quantum simulator.

    Do not include: when a synonym of spooky or enigmatic refers to concepts that follow the rules of quantum science, like photons and atoms, or that might be related to quantum science, like dark energy.

    0 = no, 1 = yes

18. If the spooky frame is present (17 is 1=yes), quote the sentence that includes the frame. If multiple sentences apply, only quote the first one.
19. Is the frame 'Quantum science (applications) lead(s) to social progress' present?

    Include: Quantum nanotechnologies could help solve societal problems (e.g. climate change and global malnutrition), or quantum nanotechnologies would impact society in a positive way.

    Do not include: If there is no mention of society being impacted, or if it is not clear whether society is impacted in a positive way (i.e. whether quantum nanotechnology brings social progress).
    For example: "Quantum nanotechnologies would change the lives of many": do not include if it does not becomes clear that the lives of many will change in a positive way.

    0 = no, 1 = yes

20. If the social progress frame is present (19 is 1=yes), quote the sentence that includes the frame. If multiple sentences apply, only quote the first one.
21. Is the frame 'economic development/competitiveness' present?
    The 'economic development/competitiveness frame' in relation to quantum science and its applications means that various parties are in competition to develop quantum nanotechnology, there is a quantum race going on. These parties invest heavily in quantum nanotechnologies. Quantum nanotechnology will provide economic growth, and will therefore have an impact on all kinds of industries.
    Note: both the social progress frame and the economic development frame can appear in a text: one frame does not exclude the other.

    > *For example: Nations should invest in quantum nanotechnologies in order to win the quantum race*

    0 = no, 1 = yes
22. If the economic development/competitiveness frame is present (21 is 1=yes), quote the sentence that includes the frame. If multiple sentences apply, only quote the first one.
23. Are benefits of quantum science (applications) mentioned?

    > *For example: quantum computers will be able to solve specific simulation and optimalisation problems exponentially faster than supercomputers currently can.*

    0 = no, 1 = yes
24. If benefits are mentioned (23 is 1=yes), quote the sentence that includes the benefit. If multiple sentences apply, only quote the first one.
25. If benefits are mentioned (23 is 1=yes): are specific fields to which the benefits apply mentioned?
    For each field, indicate whether it is mentioned (0 = no, 1 = yes).

    1 = Life sciences & health

    > *For example: using quantum simulators to develop new medicines.*

    2 = Finance

    > *For example: using quantum computers to run optimalisation algorithms to help model the risks of investment decisions.*

    3 = Logistics

    > *For example: using quantum computers to run optimalisation algorithms to model the traffic flow.*

    4 = Security & privacy

For example: data will be inherently safe against eavesdropping with the use of quantum networks.

5 = Defense

For example: using quantum sensors during military missions for navigational purposes (in case GPS cannot be used, for example in hostile environments or underground).

6 = Energy & climate

For example: using quantum computers to model better batteries.

7 = Agriculture, water and food

For example: using quantum sensors to detect water contamination.

8 = other

26. Are risks of quantum science (applications) mentioned?

    For example: quantum computers will impact the financial system, because cyber criminals can hack online banking; terrorists will be able to create new weapons by using a quantum computer; the power difference between poor and rich countries becomes bigger once the rich countries own quantum technologies whereas the poor do not.

    0 = no, 1 = yes

27. If risks are mentioned (26 is 1=yes), quote the sentence that includes the risk. If multiple sentences apply, only quote the first one.
28. If risks are mentioned (26 is 1=yes): are specific fields to which the risks apply mentioned?
    For each field, indicate whether it is mentioned (0 = no, 1 = yes).

    1 = Life sciences & health

    For example: terrorists using quantum simulators for bioterrorism purposes.

    2 = Finance

    For example: cyber criminals using quantum computers to hack into online banking.

    3 = Logistics

    For example: terrorists using quantum computers to get access to air and railroad traffic controls.

    4 = Security & privacy

    For example: governments losing their grip on criminal organizations that make use of quantum communication.

5 = Defense

For example: terrorists using quantum computers to gain access to military information.

6 = Energy & climate

For example: terrorists using quantum computers to hack into energy plants.

7 = Agriculture, water and food

For example: terrorists using quantum computers to hack into water supplies and water management.

8 = other

Quantum science explanations

29. Is the word 'superposition' mentioned?
0 = no, 1 = yes

30. Is an explanation provided of the quantum science principle: superposition?

A particle in a superposition state can be in multiple quantum states at the same time. For example, when an electron is in a superposition state, it can exist in spin states up and down at the same time.

Include: something is 0 and 1 at the same time.

Do not include: when there is no explanation present, but the speaker just mentions the word 'superposition'. For example: a qubit can be in a superposition of 0 and 1.

0 = no, 1 = yes

31. If an explanation of superposition is provided (29 is 1=yes), quote the sentence that includes the explanation. If multiple sentences apply, only quote the first one.

32. Is the word 'entanglement' mentioned?
0 = no, 1 = yes

33. Is an explanation provided of the quantum science principle: entanglement?

Two entangled particles share an extremely strong connection with each other - measuring one of the particles instantly affects the state of the other, even when the particles are separated by a large distance. In other words: entangled particles can only be described by the quantum state for the entire system, and not by their individual quantum states.

Include: two entangled particles affect each other even when they are very far apart. Also include if an analogy or metaphor is provided to explain the principle.

Do not include: holistic explanations like everything is interconnected.

0 = no, 1 = yes

34. If an explanation of entanglement is provided (32 is 1=yes), quote the sentence that includes the explanation. If multiple sentences apply, only quote the first one.

35. Is an explanation provided of the quantum science principle: contextuality?

    Contextuality means that "outcomes of measurements [depend] on other measurements on the self same system" (G. Jaeger, 2019, p 2). This is operationalised as that when one performs a measurement on a quantum state, that measurement affects the quantum state irreversibly.

    Include: a measurement or observation affects the state of a quantum system

    Do not include: when there is no mention of measurement / observation (e.g. when complementarity is mentioned but without any mention of contextuality.)

    0 = no, 1 = yes

36. If an explanation of contextuality is provided (35 is 1=yes), quote the sentence that includes the explanation. If multiple sentences apply, only quote the first one.

A2 Appendix II

A2.1 The hybrid automatic-manual process to detect duplicates

To detect duplicates, we used a hybrid automatic-manual process. We defined two articles as duplicates if they were: 1) perfect 1-to-1 copies, 2) a basic version vs. an extended/edited version, 3) a preview vs. the main article, or 4) copies of articles with small changes in individual words or clauses (i.e., not a perfect 1-to-1 copy, but articles with equal content and matching sentences for most words).

For articles to be duplicates, the overlap had thus to be at least one whole paragraph (single matching sentences were not sufficient). Exceptions to this were if two articles shared 1-to-1 paragraphs but both had at least one exclusive paragraph, we kept both in. Also, if two articles were duplicates, but they were published on dates 3 or more months apart, we kept both because to readers these articles could appear to be independent of each other and consequently result in a double salience of the topic. Also, the context and relevance of a similar article published on different dates may change over time, so that a later republished article may be perceived differently than on its original publication date. If agency reports are stretched/extended by a newspaper editor, they were also not marked as duplicates since they might contain unique content for the newspaper brand. Finally, articles that were highly similar in length and content and for which most sentences had been paraphrased were both kept in, as paraphrasing could have affected the frames.

To make sure that we detected all types of duplicates, we wrote a script that automatically evaluates the similarity of articles based on both edit- & overlap-distances to cover all the various duplicate types (we used the following similarity metrics: Damerau-Levenshtein Distance, Ratcliff/Obershelp "Distance", Overlap "Distance"). The articles that our script identified as very similar were checked manually. In order to prevent missing duplicates, we chose this minimum value to be on the low side relative to the typical similarity scores that we found for duplicates in 2009 and 2021. As a consequence, the second author still checked hundreds of article pairs manually, but this number was much lower than if we would have performed a full manual duplicate check. Articles were removed from our dataset if they met our definition of a duplicate article. Perfect 1-to-1 copies and articles with small changes in individual words or clauses merely occurred 1) for articles with related brands (e.g. NRC.NEXT and NRC, which we merged into the single code NRC); and 2) for articles from the same news brand but published on different dates (<3 months apart). In the first case, the article from the main brand (e.g. NRC) was kept in the dataset, and for the second case, the article with the latest publication date was kept in. For basic versions vs. extended/edited edition and for a preview vs. the main article, the article with the most words was kept in the dataset.

Further technical details about the automated part of this process can be found in the scripts and accompanying instructions of our code repo: https://github.com/t-rothe/quantum-in-Dutch-newspapers.

A2.2 Reasons for discarding newspaper articles as irrelevant or unsuitable for the analysis

Table A7

Total number of articles discarded from the 2,240 unique articles.

Reasons for deleting an article	Example	Total Excluded
1. Keyword "quantum" contained in (common) terms unrelated to quantum science / technology, e.g. "quantum leap", "quantum grey", a 'quantum' as in a quantity of something	"The latest campaign cleverly responds to previous quantum leaps: 'The strippenkaart became the OV-chipkaart.'"	141
2. Keyword "Quantum" used in a proper noun that is unrelated to (quantum) science / technology, e.g. a company name or product name	"Quantum of Solace" [movie] "He added that the Dutch occupants were in a Quantum-minivan belonging to tour company Eco Coaches."	599
3. Metaphorically referring to quantum (concepts) to make a point / explain something else, i.e. without further notice or explanation of (quantum) science / technology.	"Quantum mechanics states that light is a wave and a particle at the same time. [...] And now I'm actually proposing something similar where people are concerned. Can you experience another person as a fellow human being and as a stranger at the same time?"	35
4. Mentioned a word/proper noun containing the keyword "Quantum" as part of a text/document that only forms a: TV guide, table of contents for (news) articles, (event) announcements, short independent corrections on earlier articles (e.g. misspellings), or other short listings of independent and incoherent sentences / words	"SUN 5 APR Search for the lowest temperature and visible quantum phenomena. Lecture by physicist Dirk Bouwmeester."	74
5. Mentioning / Listing quantum science (concepts), technology as a scientific or technological example without further mention, explanation or discussion of the topic.	"... for example an LED, or another light source like a quantum well."	223

Reasons for deleting an article	Example	Total Excluded
6. Mentioning scientific instruments / experiments or names of other things with the keyword “Quantum” without mentioning or discussing its relation to quantum science (concepts) or technology	“The rocket carried the so-called X-Ray Quantum Calorimeter ...”	54
7. Used the topic or a concept of quantum physics / technology as an example to make a point or explain something else, i.e. without further notice of (quantum) science / technology.	“If you also want to describe what happens inside molecules, you have to do quantum mechanical calculations. But then you get nowhere - then you can only describe a hydrogen atom.”	241
8. Mentioning or listing a person or institution that is related to / works on / knows about quantum science or technology without further mention or discussion of the topic itself.	“The science battle between quantum scientist Julia Cramer and cognitive neuroscientist Barbara Braams: it will be spectacular.”	109
9. Mentioning the topic of quantum science (concepts) or technology to indicate that something unrelated is (not) difficult / (not) complex (to understand). OR Indicating that the author/someone else does not understand quantum science / technology.	“Now Kleine Goos knows as much about the [Sacred] Scripture as about quantum mechanics, ...”	33
10. Very shortly mentioning quantum physics in relation to paranormal, consciousness, reality without any explanation of the quantum physics part	“I wonder if there is something of his inner world left in his skull, an energetic quantum-like something, in a matter that I cannot observe.”	33

Note. The quotes have been translated from Dutch.

A2.3 Data of the sample

Table A8

Frequency table of the descriptives of the sample

		n	%	95% CI
Authors	Unique	117		
	Missing	60		
Number of articles	NRC	147	38.2%	[0.333, 0.430]
	De Volkskrant	130	33.8%	[0.290, 0.385]
	Trouw	54	14.0%	[0.106, 0.175]
	Algemeen Dagblad	12	3.1%	[0.014, 0.049][a]
	De Telegraaf	27	7.0%	[0.045, 0.096]
	Het Parool	15	3.9%	[0.020, 0.058]
Article type	News reports and features	234	60.8%	[0.559, 0.657]
	Opinion pieces, columns or letters	60	15.6%	[0.120, 0.192]
	Reviews of a product or announcements of upcoming events	51	13.2%	[0.099, 0.166]
	Interviews	40	10.4%	[0.073, 0.134]
Most popular	*Section:* Science	176	45.7%	[0.407, 0.507]
	Day: Saturday	215	55.8%	[0.509, 0.608]

Note. [a]indicates the exact Clopper–Pearson confidence interval was calculated.

A2.4 Intercoder reliability results

Table A10

Intercoder reliability results after coding round 3 (n = 78 articles) for the different codes that are categorised under descriptives, barriers, effective and prominent. The codes with a low agreement (Krippendorff's α < .667) are marked in red. The number of times '1' is coded is counted after the discussion. Agr. = agreement.

		#'1' coded	α	% agr.
Descriptives	Article type		0.78	88.5%
	Main focus		0.62	75.6%
	Quantum technology indicator	37	0.95	97.4%
	Quantum computing & simulation	32	0.91	97.4%
	Quantum communication	7	0.69	92.1%
	Quantum sensing & metrology	0		100%
Barriers	Spooky and enigmatic	19	0.83	93.6%
	Economic development / competitiveness	10	0.77	94.9%
	Superposition explanation	18	0.86	94.9%
	Entanglement explanation	8	1.0	100%
	Contextuality explanation	7	0.75	96.2%
	Mystical	2	0.66	98.7%
Effective	Social progress	5	0.74	97.4%
	Benefit	29	0.89	94.9%
	Risk	7	0.84	97.4%
Prominent	Spooky and enigmatic	8	0.54	80.0%
	Economic development / competitiveness	3	0.73	87.5%
	Social progress	1		100%
	Benefit	8	0.81	92.3%
	Risk	2	1.0	100%

Note. The results section also contains an analysis of the quantum science explanation prominence and mystical viewpoint prominence code. This analysis was done based on a written discussion between the first and second coder.

A2.5 Analysis plan

The analysis involved calculating the number of times *n* a code occurred, its sample proportion p and its confidence interval. As we drew a probability sample of 385 articles, these confidence intervals were 95% confidence intervals with a 5% margin of error, meaning we have a 95% confidence that the true population proportion is within 5% of the sample proportion. Before calculating the confidence intervals, we first checked the assumption of at least 15 occurrences and 15 non-occurrences of a code such that $mp \geq 15$ and $m(1-p) \geq 15$, where m is the sample size and p is the sample proportion ('Basic Statistics', n.d.). If the assumption was not met, we calculated the exact Clopper-Pearson confidence interval instead (indicated with a [a] in the Results section), which is a more conservative measure ('Epitools - Calculate confidence limits for a sample prop ...' n.d.).

A2.6 Prominence of frames in news reports and features

Table A12

Frequency table of the prominent themes in news reports and features (n = 234). The percentage given is with respect to the total number of prominent themes (n = 61).

Frame	Total number of times the frame is prominent	Percentage compared to total number of prominent frames (*n* = 61)	95% CI
Spooky and enigmatic	15	24.6%	[0.138, 0.354]
Economic development / competitiveness	6	9.8%	[0.037, 0.202][a]
quantum phenomenon explanations for articles with quantum technology indicator (*n* = 132)	11	18.0	[0.094, 0.300][a]
Mystical viewpoint	2	3.3%	[0.004, 0.114][a]
Social progress	1	1.6%	[0.000, 0.088][a]
Benefit	25	41.0%	[0.286, 0.533]
Risk	3	4.9%	[0.010, 0.137]

Note. Multiple prominent frames can occur in one article. In total, 49 articles put at least one of the frames in a prominent position. [a]indicates the exact Clopper–Pearson confidence interval was calculated.

A2.7 Additional figures

Figure A4

Number of articles by year of publication in total dataset (N = 698).

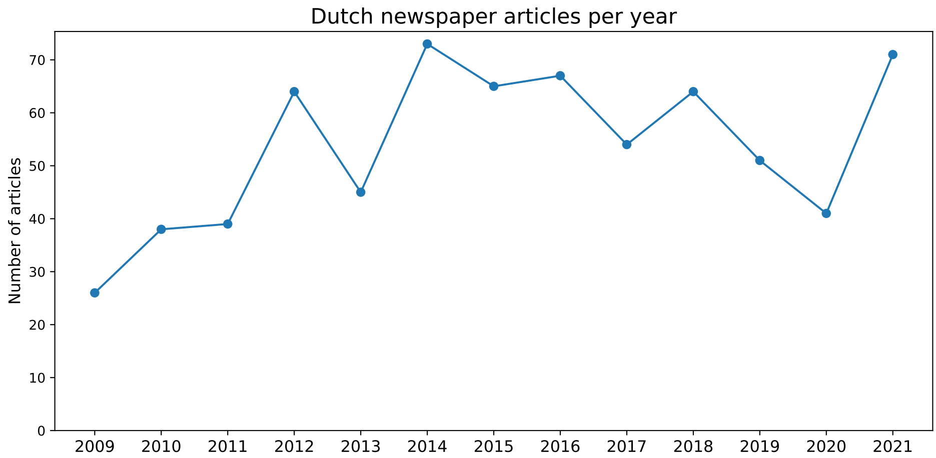


Figure A5

Number of articles by year of publication per newspaper brand (N = 385).

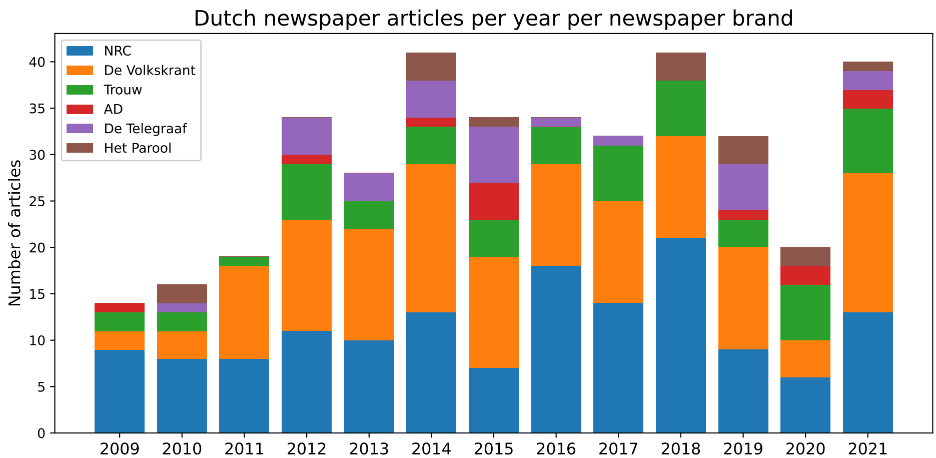


Figure A6

The percentage of articles that explain superposition, entanglement or contextuality when referring to quantum technology. The error bars are based on the sampling.

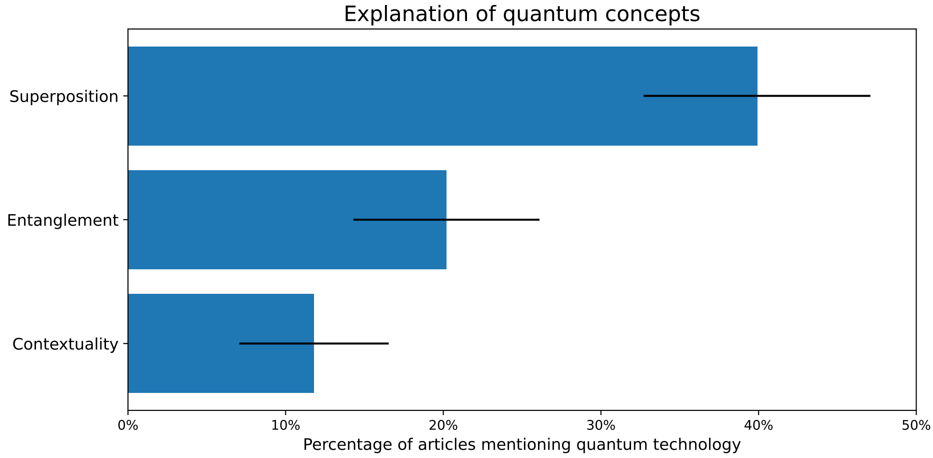
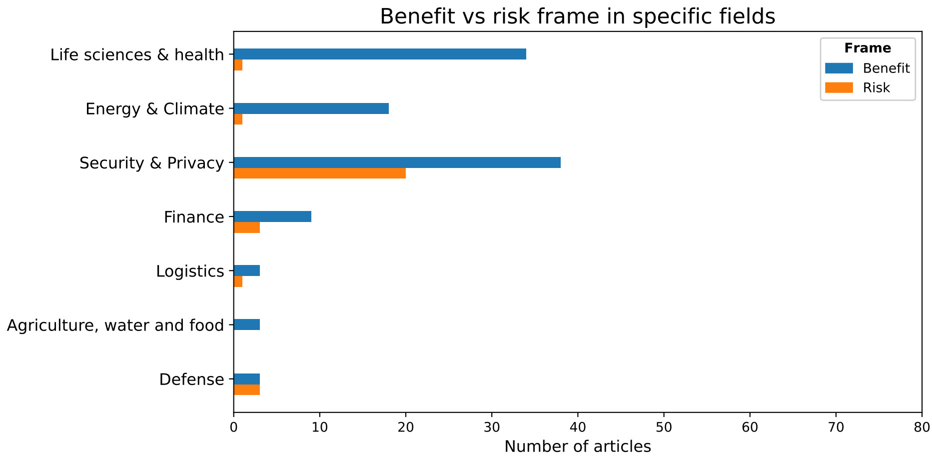


Figure A7

Number of times a specific field was mentioned in terms of benefits and risks.



A3 Appendix III

A3.1 Rationale for the 2 x 2 x 4 between-subjects design

In this study, we opted for a 2 (enigmatic, not enigmatic) x 2 (explanation, no explanation) x 4 (none, benefit, risk, balanced) between-subjects design. This is opposed to a simpler approach that might include only separate conditions for an enigmatic frame, an explanation frame, a benefit frame, a risk frame, a balanced frame, and a control condition. There are two reasons for our 2x2x4 design:

(a) A 2x2x4 design answers our research questions better.

A 2x2x4 design answers our research questions more precisely than a simpler approach. To clarify this, we focus first on the simplified 2 (enigmatic, not enigmatic: A = 0 or 1) x 2 (explanation, no explanation: B = 0 or 1) design. The extension to the third dimension is conceptually obvious.
In the 2x2 design, there are four conditions possible:

	No explanation (B = 0)	Explanation (B = 1)
Not enigmatic (A = 0)	(a)	(b)
Enigmatic (A = 1)	(c)	(d)

The simpler design would involve a control group that is similar per test: one for the effect of providing an explanation (comparison of (a) with (b)) and one for the effect of an enigmatic frame (comparison of (a) and (c)). It does not include (d). In our 2x2x4 design, we can investigate whether the effect of A differs based on the presence or absence of B – something we cannot when we would have used the simpler design. We are thus able to compare the average scores across conditions (for example, the effect of A is measured by comparing ((a)+(b))/2 with ((c)+(d))/2), and therefore we get a better picture of the general pattern. The 2x2x4 design thus answers the research questions better.

(a) A 2x2x4 design is more efficient.

In addition to better addressing our research questions, a 2x2x4 design is also more efficient as opposed to such a simpler design. Suppose a power analysis indicates that 50 participants are needed per group. In the simpler design, this requires a total of 150 participants: 50 in the control group (a), 50 in the experimental group (b) and 50 in the experimental group (c).

In a 2x2x4 design, only 100 participants are needed: 25 for (a) to (d) each. For example, when evaluating the effect of the enigmatic frame (A), we combine conditions (a) and (b) and compare them with conditions (c) and (d), allowing a comparison of 50 with 50 participants. The approach therefore either requires fewer participants or increases statistical power, making the design more efficient.

Table A15

Wordings for the 16 experimental conditions

Nr	Group	Wordings for Experimental Conditions (in Dutch)	Wordings for Experimental Conditions (translated to English)
1	Control group	Control group statement: "Quantumtechnologie is een opkomende technologie. Quantumtechnologie gebruikt wetenschappelijke kennis die de allerkleinste deeltjes beschrijft, zoals elektronen."	Control group statement: "Quantum technology is an emerging technology. Quantum technology uses scientific knowledge that describes the smallest particles, such as electrons."
2	Enigmatic frame group	Enigmatic frame statement: "Quantumtechnologie is een opkomende technologie. Quantumtechnologie gebruikt wetenschappelijke kennis die de allerkleinste deeltjes, zoals elektronen, op een raadselachtige manier beschrijft."	Enigmatic frame statement: "Quantum technology is an emerging technology. Quantum technology uses scientific knowledge that describes the smallest particles, such as electrons, in a mysterious way."
3	Explanation of a quantum phenomenon group	Control group statement + One of the following 6 statements (Explanation frame statement):	Control group statement + One of the following 6 statements (Explanation frame statement):
	1a) Superposition - definition	1a) "Zo zegt deze wetenschap dat het voor kleine deeltjes mogelijk is om op twee plaatsen tegelijkertijd te zijn. Dit is iets dat we in ons dagelijks leven niet zien. In ons dagelijks leven kan iets maar op één plek tegelijkertijd zijn."	1a) "For example, this science says that it is possible for small particles to be in two places at the same time. This is something that we don't see in our daily lives. In our daily lives, something can only be in one place at the time."
	1b) Superposition - analogy	1b) "Zo zegt deze wetenschap dat het voor kleine deeltjes mogelijk is om op twee plaatsen tegelijkertijd te zijn. Stel dat dit ook voor een auto zou gelden. Dan zou een auto op twee verschillende wegen tegelijk kunnen rijden, bijvoorbeeld op de A2 en tegelijkertijd op de A28. Dit is iets dat we in ons dagelijks leven niet zien. In ons dagelijks leven rijdt een auto óf op de A2 óf op de A28."	1b) "For example, this science says that it is possible for small particles to be in two places at the same time. Suppose this also applies to a car. Then a car could drive on two different roads at the same time, for example on the A2 and at the same time on the A28. This is something we don't see in our daily lives. In our daily lives, a car either drives on the A2 or the A28."

Nr	Group	Wordings for Experimental Conditions (in Dutch)	Wordings for Experimental Conditions (translated to English)
	2a) Entanglement - definition	2a) “Zo zegt deze wetenschap dat twee kleine deeltjes die ver weg zijn, toch sterk met elkaar verbonden zijn. Als de toestand van het ene deeltje verandert, verandert de toestand van het andere deeltje onmiddellijk mee. Dit is iets wat we in ons dagelijks leven niet zien.”	2a) “For example, this science says that two small particles that are far away are still strongly connected. If the state of one particle changes, the state of the other particle changes immediately. This is something we don’t see in our daily lives.”
	2b) Entanglement - analogy	2b) “Zo zegt deze wetenschap dat twee kleine deeltjes in een gezamenlijke toestand kunnen zijn. Daardoor heeft het geen zin meer om over deze twee deeltjes te praten alsof het twee afzonderlijke deeltjes zijn. Stel dat dit ook voor twee gekleurde ballen zou gelden. Als de ballen in een gezamenlijke toestand zijn en je kijkt naar de kleur van één bal, dan kan dat onmiddellijk de kleur van de andere bal beïnvloeden. Ook al is die andere bal mijlenver weg.”	2b) “For example, this science says that two small particles can be in a joint state. As a result, it no longer makes sense to talk about these two particles as if they were two separate particles. Suppose this also applies to two coloured balls. If the balls are in a joint state and you look at the colour of one ball, it can immediately affect the colour of the other ball. Even though the other ball is miles away.”
	3a) Contextuality - definition	3a) “Zo zegt deze wetenschap dat door naar een deeltje te kijken, de eigenschappen van dat deeltje kunnen veranderen. Dit is iets wat we in ons dagelijks leven niet ervaren. In ons dagelijkse leven verandert iets niet van eigenschap, zoals van kleur of vorm, alleen maar door ernaar te kijken.”	3a) “For example, this science says that by looking at a particle, the properties of that particle can change. This is something we do not experience in our daily lives. In our daily lives, something does not change its properties, such as colour or shape, just by looking at it.”
	3b) Contextuality - analogy	3b) “Zo zegt deze wetenschap dat door naar een deeltje te kijken, de eigenschappen van dat deeltje kunnen veranderen. Stel dat dit ook voor een trui zou gelden: zodra u naar de trui kijkt is deze bijvoorbeeld groen. Als u wegkijkt, en een stuk later opnieuw naar de trui kijkt, is de trui opeens grijs. Het kijken naar de trui heeft een fysiek effect op die trui.”	3b) “For example, this science says that by looking at a particle, the properties of that particle can change. Suppose this also applies to a sweater: as soon as you look at the sweater it is for example green. If you look away and look at the sweater again a little later, the sweater is suddenly grey. Looking at the sweater has a physical effect on that sweater.”

Nr	Group	Wordings for Experimental Conditions (in Dutch)	Wordings for Experimental Conditions (translated to English)
4	Benefit frame group	Control group statement + Benefit frame statement: "Sommige wetenschappers zeggen dat quantumtechnologie in de toekomst levens kan gaan redden of verlengen. Volledig ontwikkelde quantumtechnologie heeft namelijk de potentie om nieuwe medicijnen te ontwerpen."	Control group statement + Benefit frame statement: "Some scientists say that quantum technology could save or extend lives in the future. Fully developed quantum technology has the potential to design new medicines."
5	Risk frame group	Control group statement + Risk frame statement: "Sommige wetenschappers zeggen dat quantumtechnologie in de toekomst veiligheidsproblemen kan gaan veroorzaken. Volledig ontwikkelde quantumtechnologie heeft namelijk de potentie om gebruikt te worden voor cyberoorlogsvoering."	Control group statement + Risk frame statement: "Some scientists say that quantum technology could cause safety problems in the future. Fully developed quantum technology has the potential to be used for cyber warfare."
6	Balanced frame group	Control group statement + Balanced frame statement: "Sommige wetenschappers zeggen dat quantumtechnologie in de toekomst levens kan gaan redden of verlengen. Volledig ontwikkelde quantumtechnologie heeft namelijk de potentie om nieuwe medicijnen te ontwerpen. Andere wetenschappers zeggen dat quantumtechnologie in de toekomst veiligheidsproblemen kan gaan veroorzaken. Volledig ontwikkelde quantumtechnologie heeft namelijk de potentie om gebruikt te worden voor cyberoorlogsvoering."	Control group statement + Balanced frame statement: "Some scientists say that quantum technology could save or extend lives in the future. Fully developed quantum technology has the potential to design new medicines. Other scientists say that quantum technology could cause safety problems in the future. Fully developed quantum technology has the potential to be used for cyber warfare."
7	Enigmatic frame + Explanation of a quantum phenomenon group	Enigmatic frame statement + Explanation of a quantum phenomenon statement	Enigmatic frame statement + Explanation of a quantum phenomenon statement
8	Enigmatic frame + Benefit frame group	Enigmatic frame statement + Benefit frame statement	Enigmatic frame statement + Benefit frame statement
9	Enigmatic frame + Risk frame group	Enigmatic frame statement + Risk frame statement	Enigmatic frame statement + Risk frame statement
10	Enigmatic frame + Balanced frame group	Enigmatic frame statement + Balanced frame statement	Enigmatic frame statement + Balanced frame statement

Nr	Group	Wordings for Experimental Conditions (in Dutch)	Wordings for Experimental Conditions (translated to English)
11	Explanation of a quantum phenomenon + Benefit frame group	Control group statement + Explanation of a quantum phenomenon statement + Benefit frame statement	Control group statement + Explanation of a quantum phenomenon statement + Benefit frame statement
12	Explanation of a quantum phenomenon + Risk frame group	Control group statement + Explanation of a quantum phenomenon statement + Risk frame statement	Control group statement + Explanation of a quantum phenomenon statement + Risk frame statement
13	Explanation of a quantum phenomenon + Balanced frame group	Control group statement + Explanation of a quantum phenomenon statement + Balanced frame statement	Control group statement + Explanation of a quantum phenomenon statement + Balanced frame statement
14	Enigmatic frame + Explanation of a quantum phenomenon + Benefit frame group	Enigmatic frame statement + Explanation of a quantum phenomenon statement + Benefit frame statement	Enigmatic frame statement + Explanation of a quantum phenomenon statement + Benefit frame statement
15	Enigmatic frame + Explanation of a quantum phenomenon + Risk frame group	Enigmatic frame statement + Explanation of a quantum phenomenon statement + Risk frame statement	Enigmatic frame statement + Explanation of a quantum phenomenon statement + Risk frame statement
16	Enigmatic frame + Explanation of a quantum phenomenon + Balanced frame group	Enigmatic frame statement + Explanation of a quantum phenomenon statement + Balanced frame statement	Enigmatic frame statement + Explanation of a quantum phenomenon statement + Balanced frame statement

Table A16

Engagement questions

Outcome variable	Cronbach's α	Statements (in Dutch)	Statements (translated to English)
Information seeking	3-item scale; α = 0.94	1. Ik ben van plan om binnenkort informatie over quantumtechnologie op te zoeken 2. Ik zal proberen om in de komende tijd informatie over quantumtechnologie op te zoeken 3. Het is mijn bedoeling om meer te weten te komen over quantumtechnologie	1. I plan to seek information about quantum technology in the near future 2. I will try to seek information about quantum technology in the near future 3. I intend to find out more information about quantum technology
Internal efficacy	4-item scale; α = 0.859	1. Ik denk dat ik goed in staat ben om deel te nemen aan discussies over quantumtechnologie 2. Ik heb het gevoel dat ik een redelijk goed begrip heb van de belangrijke kwesties rond quantumtechnologie waarmee Nederland wordt geconfronteerd 3. Ik heb het gevoel dat ik net zo goed een oordeel kan leveren op het gebied van quantumtechnologie als de meeste andere mensen 4. Ik denk dat ik beter geïnformeerd ben over quantumtechnologie dan de meeste mensen	1. I consider myself to be well qualified to participate in discussions about quantum technology 2. I feel that I have a pretty good understanding of the important quantum technology issues facing the country 3. I feel that I could do as good a job in the quantum technology field as most other people 4. I think that I am better informed about quantum technology than most people

Outcome variable	Cronbach's α	Statements (in Dutch)	Statements (translated to English)
General interest	6-item scale; α = 0.892	1. Ik wil meer leren over quantumtechnologie 2. Ik vind het debat rond quantumtechnologie interessant 3. Ik wil mij gaan verdiepen in quantumtechnologie 4. Ik ben nieuwsgierig geworden naar quantumtechnologie 5. Ik vind quantumtechnologie saai (reverse-coded) 6. Wat ik net heb gelezen over quantumtechnologie levert stof tot nadenken	1. I am interested in learning about quantum technology 2. I find the debate surrounding quantum technology interesting 3. I want to learn more about quantum technology 4. Quantum technology is exciting 5. I find quantum technology boring (reverse-coded) 6. These quantum technological ideas were thought-provoking
Perceived knowledge	4-item scale; We worked with items 1, 2 and 4 resulting in α = 0.848	1. Ik heb kennis over quantumtechnologie 2. Ik voel me goed geïnformeerd over zaken rond quantumtechnologie 3. Ik weet niet zoveel als ik zou willen weten over zaken rond quantumtechnologie (reverse-coded) 4. Ik heb vertrouwen in mijn begrip rond quantumtechnologie	1. I am knowledgeable about quantum technology 2. I am well-informed about issues related to quantum technology 3. I don't know as much as I'd like to know about the issues surrounding quantum technology (reverse-coded) 4. I trust my knowledge about quantum technology

A4 Appendix IV

A4.1 Text of stimulus material and different conditions

Participants were assigned to read a newspaper article about quantum containing either a metaphorical or non-metaphorical explanation of superposition or entanglement or no explanation at all. The original Dutch version and the English version, translated with the help of Google Translate and checked by all authors, are found below.

Original Dutch version

Nieuwe quantumcomputer voor Nederland

Nederland krijgt een van de acht nieuwe quantumcomputers die de Europese Commissie laat bouwen. Hiermee hopen ze Europa een betere concurrentiepositie te geven op het gebied van quantumtechnologie.

23 Oktober 2024

De Nederlandse quantumcomputer kost 20 miljoen euro. Hij komt op het Amsterdam Science Park en wordt naar verwachting in de zomer van 2026 gebouwd. Quantumcomputers werken anders dan de computers die we nu gebruiken. Ze maken gebruik van de principes van de quantumfysica, een domein binnen de natuurkunde dat zich bezighoudt met de allerkleinste deeltjes. Een belangrijk kenmerk daarin is *superpositie/verstrengeling*. Quantumcomputers maken onder andere gebruik van *superpositie/verstrengeling*, waardoor ze in de toekomst mogelijk bepaalde problemen sneller kunnen oplossen dan onze huidige computers.

	Item: Superpositie	Item: Verstrengeling
Conditie: Control	*No text.* (0 words)	*No text.* (0 words)
Conditie: Niet-metaforisch	Superpositie is een quantumfenomeen. Een deeltje in superpositie bevindt zich niet slechts in één toestand. Zolang het deeltje in superpositie is, is het in een combinatie van verschillende toestanden tegelijkertijd. Deze situatie blijft bestaan totdat we het deeltje meten. Pas als we een meting aan het deeltje doen komt het deeltje in één toestand. Deeltjes in de quantumwereld kunnen dus tegelijkertijd in meerdere toestanden bestaan totdat ze worden gemeten of waargenomen. Zo werkt het in de quantumwereld. (77 words)	Verstrengeling is een quantumfenomeen. Als twee deeltjes verstrengeld zijn, betekent dit dat hun toestanden op een bepaalde manier met elkaar verbonden zijn. Als je de toestand van het ene deeltje meet, weet je direct wat de toestand van het andere deeltje is. Zelfs als die deeltjes zich aan weerszijden van het universum bevinden. De toestand van het ene deeltje zorgt er dus voor dat de toestand van het deeltje waarmee het verstrengeld is vastligt. Zo werkt het in de quantumwereld. (80 words)
Conditie: Metaforisch	Superpositie is een quantumfenomeen. Een deeltje in superpositie kun je vergelijken met een muntje dat in de lucht draait. Zolang het muntje draait lijkt het alsof het tegelijkertijd kop en munt is. Deze situatie blijft bestaan totdat we de munt op tafel slaan. Pas als we de munt op tafel slaan komt het muntje op kop óf munt terecht. Het muntje lijkt dus tegelijkertijd kop én munt totdat het wordt gemeten of waargenomen. Zo werkt het in de quantumwereld. (79 words)	Verstrengeling is een quantumfenomeen. Verstrengelde deeltjes kun je vergelijken met een paar dobbelstenen waarbij de uitkomsten altijd hetzelfde zijn. Wanneer de ene dobbelsteen wordt gegooid, is de uitkomst van de andere dobbelsteen direct bepaald. Zelfs als deze aan de andere kant van de speeltafel wordt gegooid. De uitkomst van de ene dobbelsteen zorgt er dus voor dat de uitkomst van de dobbelsteen waarmee die verbonden is vastligt. Zo werkt het in de quantumwereld. (73 words)

De komst van een quantumcomputer is een belangrijk moment voor de concurrentiepositie van Nederland in quantumtechnologie. Maar wat de technologie precies voor jou en mij gaat betekenen is nog onduidelijk. De betrokken onderzoekers hopen hier met dit project meer over te weten te komen.

Translated English version

New quantum computer for the Netherlands

The Netherlands will receive one of eight new quantum computers that the European Commission is having built. They hope that this will give Europe a better competitive position in the field of quantum technology.

23 October 2024

The Dutch quantum computer costs 20 million euros. It will be located at the Amsterdam Science Park and is expected to be built in the summer of 2026. Quantum computers work differently than the computers we use now. They use the principles of quantum physics, a domain within physics that deals with the smallest particles. An important characteristic of this is *superposition/entanglement*. Quantum computers use *superposition/entanglement*, among other things, as a result of which, in the future, they may be able to solve certain problems faster than our current computers can.

	Item: Superposition	*Item: Entanglement*
Condition: Control	*No text.* (0 words)	*No text.* (0 words)
Condition: Non-metaphorical	Superposition is a quantum phenomenon. A particle in superposition is not just in one state. As long as the particle is in superposition, it is in a combination of different states at the same time. This situation continues until we measure the particle. Only when we perform a measurement on the particle does the particle enter a single state. Particles in the quantum world can therefore exist in multiple states at the same time until they are measured or observed. This is how the quantum world works.	Entanglement is a quantum phenomenon. When two particles are entangled, it means that their states are somehow connected. If you measure the state of one particle, you immediately know what the state of the other particle is. Even if those particles are on opposite sides of the universe. So the state of one particle ensures that the state of the particle it is entangled with is fixed. This is how the quantum world works.
Condition: Metaphorical	Superposition is a quantum phenomenon. A particle in superposition can be compared to a coin spinning in the air. As long as the coin is spinning, it appears to be heads and tails at the same time. This situation continues until we slap the coin on the table. Only when we slap the coin on the table does the coin land on either heads or tails. The coin therefore appears to be heads and tails at the same time until it is measured or observed. That is how it works in the quantum world.	Entanglement is a quantum phenomenon. Entangled particles can be compared to a pair of dice where the outcomes are always the same. When one die is thrown, the outcome of the other die is immediately determined. Even if it is thrown on the other side of the gaming table. The outcome of one die therefore ensures that the outcome of the die it is connected to is fixed. That is how it works in the quantum world.

The arrival of a quantum computer is an important moment for the competitive position of the Netherlands in quantum technology. But what the technology will mean exactly for you and me is still unclear. The researchers involved hope to find out more about this with this project.

A4.2 Intercoder reliability on actual comprehension

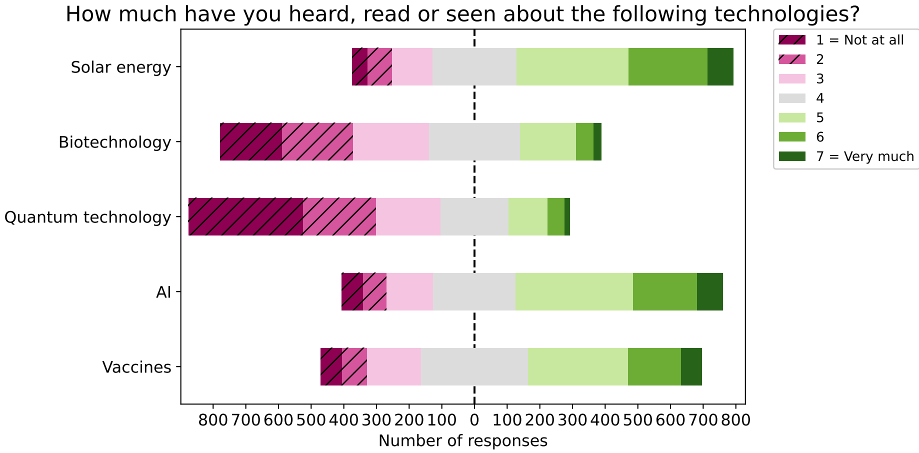
To ensure the reliability of the results on actual comprehension, two coders discussed the first 50 answers and rated the answers together. The two coders agreed in all cases and afterwards independently coded a sample of 10% of the answers (n = 117) to calculate intercoder agreement. We found perfect to near-perfect agreement between the coders for superposition and entanglement with α values between 0.86 and 1 (percent agreements between 96% - 100%), except for 2) there is a connection/correlation (α = 0.54, 84%). We modified this code slightly by specifying that using a synonym of connection/correlation, such as cooperation or fusion, would also be awarded a point. Furthermore, no point would be awarded if the answer only mentioned connection/correlation, without specifying that it was between something, such as small particles. Afterwards, the first coder coded the remaining 1,009 answers.

A4.3 Control variables

Awareness of quantum. Prior awareness of quantum technology can influence comprehension when participants use it as a cue for assessment (Thiede et al., 2010) and can furthermore influence participants' attitudes with more aware participants holding more favourable attitudes (see Scheufele & Lewenstein, 2005 in the case of nanotechnology). To control for this effect, participants were asked (Scheufele & Lewenstein, 2005): *"How much have you heard, read or seen about the following technologies?" "Solar energy, Biotechnology, Quantum technology, Artificial Intelligence, Vaccines"* [1 = nothing at all, 7 = very much]. To mask the fact that we were only interested in awareness of quantum technology, we used 4 extra items shown in a random order, based on new technologies that were asked in the Special Eurobarometer 516 (European Commission, Directorate-General for Communication, 2021). In line with our expectations, awareness of quantum technology in the sample was low ($M = 2.78$, $SD = 1.60$), with 66.1% of participants (n = 773) indicating they had not heard about quantum technology at all or little [scores: 1-3]. Compared to the other new technologies that we asked about, participants scored on average lowest for awareness of quantum technology (see Figure A8).

Figure A8

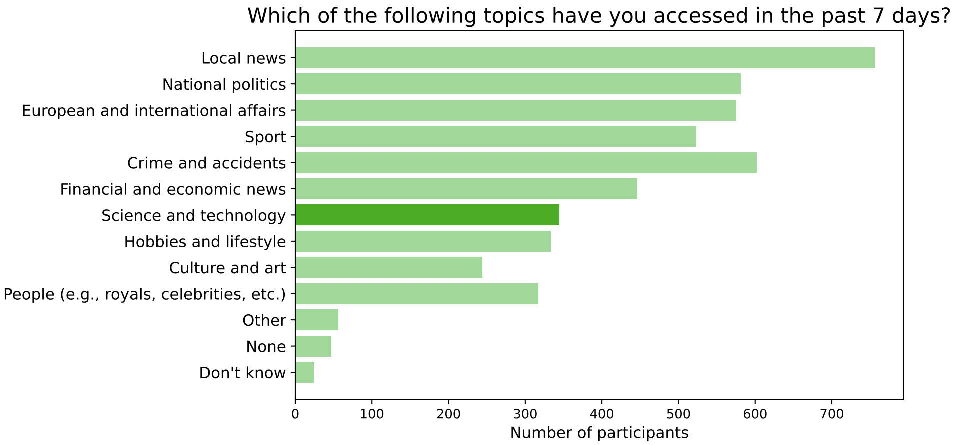
Awareness of quantum technology in comparison to other new technologies. The plots are centred around the neutral (Likert score of 4) value. (Figure created through adaptation of this Github file).



Science news use. People who tend to read the science news section in newspapers (the most popular section in which articles on quantum science and technology appear; Chapter 3) might hold more positive views on quantum technology compared to people who skip this section (see e.g., Scherrer, 2023; Scheufele & Lewenstein, 2005). Therefore, we measured participants' science news use with the item (European Parliament, 2023): *"Thinking about news and other information, which of the following topics have you accessed in the past 7 days? (Multiple answers allowed)": "Local news, National politics, European and international affairs, Sport, Crime and accidents, Financial and economic news, Science and technology, Hobbies and lifestyle, Culture and art, People (e.g., royals, celebrities, etc.), Other, None, Don't know".* We found a total of n = 344 (29.5%) had accessed science news in the past 7 days, which is slightly higher than the 24% found in 2023 by the Eurobarometer (European Parliament, 2023).

Figure A9

News use of the participants in our sample, where science news use indicates the answer 'Science and technology'.



Interest in new technology. People may use interest in a topic as a cue to judge their comprehension of a text (Thiede et al., 2010). We measured participants' interest in new technologies with 6 items adapted from Shulman et al. (2020) ("science technologies" was substituted for "new technologies"): *"I am interested in learning about new technologies", "I find the debate surrounding new technologies interesting", "I want to learn more about new technologies", "New technologies are exciting", "I find new technology boring"* (reverse coded), *"New technological ideas are thought-provoking"* [1 = strongly disagree, 7 = strongly agree]. These six items were averaged into an index ($M = 4.40$, $SD = 1.29$, Cronbach's $\alpha = 0.91$).

Faith in intuition. People who have a high faith in intuition tend to rely more on affect (van Giesen et al., 2018). Therefore, we measured participants' faith in intuition with 5 items (Epstein et al., 1996): *"I trust my initial feelings about people", "I believe in trusting my hunches", "My initial impressions of people are almost always right", "When it comes to trusting people, I can usually rely on my "gut feelings." ", "I can usually feel when a person is right or wrong even if I can't explain how I know."* [1 = completely false, 7 = completely true]. The five items were averaged into an index ($M = 4.87$, $SD = 0.95$, Cronbach's $\alpha = 0.86$).

Need for cognition. People who have a high need for cognition rely more on cognition (van Giesen et al., 2018). The 5 items were (Epstein et al., 1996): *"I don't like to have to do a lot of thinking"* (reverse coded), *"I try to avoid situations that require thinking in depth about something"* (reverse coded), *"I prefer to do something that challenges my thinking abilities rather than something that requires* *little thought", "I prefer complex to simple problems", "Thinking hard and for a long time about something gives me little satisfaction* (reverse coded)" [1 = completely false, 7 = completely true]. The five items were averaged into an index ($M = 4.57$, $SD = 1.05$, Cronbach's $\alpha = 0.75$).

A4.4 Expert insights study

Table A17 shows the metaphors presented to the experts in the expert insights study in preparation of the experiment. Note that we have slightly modified the wording of the coin and dice metaphor in the experiment in a few places compared to the text presented to the experts, in order to make the texts as similar as possible in structure to the non-metaphorical version of the text. However, the metaphorical content has not changed.

Table A17

The metaphors used in the expert insights study, which were generated by ChatGPT 3.5 and modified to ensure similar structure.

Metaphor	Original Dutch text	Translated English text
Superposition		
A coin spinning in the air	Quantumsuperpositie is als een munt die in de lucht draait. Totdat we de munt op tafel slaan, is het alsof de munt tegelijkertijd kop en munt is. Echter, zodra we de munt op tafel slaan, komt de munt op kop óf munt terecht. Dit illustreert hoe deeltjes in de quantumwereld tegelijkertijd in meerdere toestanden kunnen bestaan totdat ze worden gemeten of waargenomen, net zoals een munt zowel kop als munt is totdat we de munt op tafel slaan.	Quantum superposition is like a coin spinning in the air. Until we hit the coin on the table, it is as if the coin is both heads and tails at the same time. However, as soon as we hit the coin on the table, the coin lands either heads or tails. This illustrates how particles in the quantum world can exist in multiple states at the same time until they are measured or observed, just as a coin is both heads and tails until we hit it on the table.

Metaphor	Original Dutch text	Translated English text
A radio producing a jumble of sounds	Quantumsuperpositie is als een radio die een wirwar aan geluiden voortbrengt. Totdat de radio-ontvanger aan een zender is gekoppeld, is het alsof de radio tegelijkertijd op alle mogelijke zenders is afgestemd. Echter, zodra de radio-ontvanger aan een zender is gekoppeld, stemt de radio meteen nog maar op één van de mogelijke zenders af. Dit illustreert hoe deeltjes in de quantumwereld tegelijkertijd in meerdere toestanden kunnen bestaan totdat ze worden gemeten of waargenomen, net zoals de radio op alle mogelijke zenders is afgestemd totdat de radio-ontvanger aan een zender is gekoppeld.	Quantum superposition is like a radio that produces a jumble of sounds. Until the radio receiver is hooked up to a transmitter, it is as if the radio is tuned to all possible channels at once. However, as soon as the radio receiver is hooked up to a transmitter, the radio immediately tunes to only one of the possible channels. This illustrates how particles in the quantum world can exist in multiple states at once until they are measured or observed, just as the radio is tuned to all possible channels until the radio receiver is hooked up to a transmitter.
A cat, a vial of poison and a radioactive atom in a locked box	Quantumsuperpositie is als een kat, een flesje gif en een radioactief atoom in een afgesloten doos. Totdat we de doos openen, is het alsof de kat tegelijkertijd levend en dood is. Echter, zodra we de doos openen zien we dat óf het atoom is vervallen waardoor het flesje gif is gebroken en de kat is gedood, óf dat het atoom niet is vervallen en de kat levend is. Dit illustreert hoe deeltjes in de quantumwereld tegelijkertijd in meerdere toestanden kunnen bestaan totdat ze worden gemeten of waargenomen, net zoals een kat zowel levend als dood is totdat we de doos openen.	Quantum superposition is like a cat, a vial of poison, and a radioactive atom in a sealed box. Until we open the box, it is as if the cat is both alive and dead at the same time. However, once we open the box, we see that either the atom has decayed, breaking the vial of poison and killing the cat, or the atom has not decayed and the cat is alive. This illustrates how particles in the quantum world can exist in multiple states at the same time until they are measured or observed, just as a cat is both alive and dead until we open the box.

Metaphor	Original Dutch text	Translated English text
An artist dabbing his brush in multiple colours	Quantumsuperpositie is als een kunstenaar die zijn penseel in meerdere kleuren dept. Totdat het penseel het canvas raakt, is het alsof het penseel tegelijkertijd in alle mogelijke kleurencombinaties aanwezig is. Echter, zodra het penseel het canvas raakt, laat het canvas meteen nog maar één van de mogelijke kleurencombinaties zien. Dit illustreert hoe deeltjes in de quantumwereld tegelijkertijd in meerdere toestanden kunnen bestaan totdat ze worden gemeten of waargenomen, net zoals het penseel zich in alle mogelijke kleurencombinaties bevindt totdat het penseel het canvas raakt.	Quantum superposition is like an artist dabbing his brush in multiple colors. Until the brush touches the canvas, it is as if the brush is in all possible color combinations at the same time. However, as soon as the brush touches the canvas, the canvas immediately shows only one of the possible color combinations. This illustrates how particles in the quantum world can exist in multiple states at the same time until they are measured or observed, just as the brush is in all possible color combinations until it touches the canvas.
A musician composing a music piece	Quantumsuperpositie is als een muzikant die een muziekstuk componeert en meerdere muzieknoten op hetzelfde blad plaatst. Totdat de muzikant de partituur speelt, is het alsof de muziek zich tegelijkertijd in alle mogelijke melodieën bevindt. Echter, zodra de muzikant de partituur speelt, bevindt de muziek zich meteen nog maar in één van de mogelijke melodieën. Dit illustreert hoe deeltjes in de quantumwereld tegelijkertijd in meerdere toestanden kunnen bestaan totdat ze worden gemeten of waargenomen, net zoals de muziek zich in alle mogelijke melodieën bevindt totdat de muzikant de partituur speelt.	Quantum superposition is like a musician composing a piece of music and placing multiple notes on the same sheet of paper. Until the musician plays the score, it is as if the music is in all possible melodies at once. However, as soon as the musician plays the score, the music is immediately in only one of the possible melodies. This illustrates how particles in the quantum world can exist in multiple states at once until they are measured or observed, just as the music is in all possible melodies until the musician plays the score.
Entanglement		

Metaphor	Original Dutch text	Translated English text
A pair of dice	Quantumverstrengeling is als het gooien van een paar dobbelstenen. Wanneer de ene dobbelsteen wordt gegooid, is de uitkomst van de andere dobbelsteen vooraf bepaald, zelfs als deze aan de andere kant van de speeltafel wordt gegooid. Dit illustreert hoe in de quantumwereld de toestand van het ene deeltje de toestand bepaalt van het deeltje waarmee het verstrengeld is, net zoals de uitkomst van de ene dobbelsteen de uitkomst van de andere dobbelsteen bepaalt.	Quantum entanglement is like rolling a pair of dice. When one die is rolled, the outcome of the other die is predetermined, even if it is rolled on the other side of the gaming table. This illustrates how in the quantum world, the state of one particle determines the state of the particle it is entangled with, just as the outcome of one die determines the outcome of the other die.
Two dancers performing a perfectly synchronized dance routine	Quantumverstrengeling is als twee dansers die een perfect gesynchroniseerde dansroutine uitvoeren. Wanneer de ene danser beweegt, beweegt de andere danser op een gecoördineerde manier alsof ze een onzichtbare link delen, zelfs als ze zich aan andere kanten van het podium bevinden. Dit illustreert hoe in de quantumwereld de toestand van het ene deeltje de toestand bepaalt van het deeltje waarmee het verstrengeld is, net zoals de bewegingen van de ene danser de bewegingen van de andere danser bepalen.	Quantum entanglement is like two dancers performing a perfectly synchronized dance routine. When one dancer moves, the other dancer moves in a coordinated manner as if they share an invisible link, even if they are on opposite sides of the stage. This illustrates how in the quantum world, the state of one particle determines the state of the particle it is entangled with, just as the movements of one dancer determine the movements of the other dancer.
A telepathic twin	Quantumverstrengeling is als een telepathische tweeling die onmiddellijk elkaars gedachten kan kennen. Wanneer de ene tweeling van gedachten verandert, verandert de ander onmiddellijk ook van gedachten, zelfs als ze zich aan andere kanten van de planeet bevinden. Dit illustreert hoe in de quantumwereld de toestand van het ene deeltje de toestand bepaalt van het deeltje waarmee het verstrengeld is, net zoals de gedachten van de ene tweeling de gedachten van de andere tweeling bepalen.	Quantum entanglement is like a pair of telepathic twins who can instantly know each other's thoughts. When one twin changes their mind, the other instantly changes their mind too, even if they are on opposite sides of the planet. This illustrates how in the quantum world, the state of one particle determines the state of the particle it is entangled with, just as the thoughts of one twin determine the thoughts of the other twin.

Metaphor	Original Dutch text	Translated English text
Two compass needles that always point in opposite directions	Quantumverstrengeling is als het hebben van twee kompasnaalden die altijd in tegengestelde richtingen wijzen. Wanneer je de ene naald naar het noorden draait, wijst de andere onmiddellijk naar het zuiden, ook al bevinden ze zich aan de andere kant van de zeilboot. Dit illustreert hoe in de quantumwereld de toestand van het ene deeltje de toestand bepaalt van het deeltje waarmee het verstrengeld is, net zoals het draaien van de naald van het ene kompas de naald van het andere kompas aanpast.	Quantum entanglement is like having two compass needles that always point in opposite directions. When you turn one needle north, the other immediately points south, even though they are on opposite sides of the sailboat. This illustrates how in the quantum world, the state of one particle determines the state of the particle it is entangled with, just as turning the needle of one compass adjusts the needle of the other compass.
Two clocks with perfectly synchronized second hands	Quantumverstrengeling is als twee klokken waarvan de secondewijzers perfect gesynchroniseerd zijn. Wanneer u de tijd op de ene klok wijzigt, past de andere zich onmiddellijk aan, zelfs als deze zich aan de andere kant van de kamer bevindt. Dit illustreert hoe in de quantumwereld de toestand van het ene deeltje de toestand bepaalt van het deeltje waarmee het verstrengeld is, net zoals het veranderen van de tijd op de ene klok de tijd op de andere klok aanpast.	Quantum entanglement is like two clocks with perfectly synchronized second hands. When you change the time on one clock, the other clock immediately adjusts, even if it is across the room. This illustrates how in the quantum world, the state of one particle determines the state of the particle it is entangled with, just as changing the time on one clock changes the time on the other clock.

A4.5 The variety of explanations from experts for their rankings

Table A18 shows the variety of answers given to the question: “If you were to use a comparison in a conversation with non-quantum experts about quantum superposition/quantum entanglement, which of these would you use? Rank them in order from most likely to least likely.”

Table A18

Answers to the question 'Please explain your ranking'. Answers are grouped, translated and edited for clarity.

Superposition		
Metaphor	Positive	Negative
A coin spinning in the air	1. The metaphor best illustrates that the outcome of the measurement is indeterminate until a measurement is performed. 2. The metaphor provides the most minimalistic and simplest explanation. 3. The metaphor lends itself best to subsequently explain other concepts such as entanglement, measurement, quantum key distribution etc. 4. The metaphor best illustrates that a measurement provides a kind of probability of different outcomes. 5. The metaphor appeals to the imagination of people and appeals to the largest audience.	1. The metaphor explains what chance is (classical statistics), not what superposition is. 2. The metaphor does not take into account that you can change bases.
A radio producing a jumble of sounds	1. The metaphor best illustrates that superpositions are real, in the sense that they were not simply randomly generated. 2. The metaphor is most accurate, because it explicitly places the importance of a measurement in the description.	1. The metaphor brings with it all sorts of nuances that only confuse people more. 2. The metaphor is not correct. 3. The metaphor is incomprehensible. 4. The metaphor is too specific, which means it only appeals to the imagination of a limited number of people.
A cat, a vial of poison and a radioactive atom in a locked box	1. The metaphor is very well known and therefore resonates better. 2. The metaphor is nice to explain entanglement.	1. The metaphor is not correct. 2. The metaphor is too complicated to convey. 3. The metaphor is too specific, which means it only appeals to the imagination of a limited number of people.

Metaphor	Positive	Negative
An artist dabbing his brush in multiple colours		1. The metaphor brings all kinds of nuances that only confuse people more. 2. The metaphor unnecessarily brings the problem of mixing colour into it. 3. The metaphor is not valid. 4. The metaphor does not illustrate the quantum aspect enough, because if you dab a brush in multiple colours, there will probably be multiple colours on the canvas. 5. The metaphor is too specific, which means that it only appeals to the imagination of a limited number of people.
A musician composing a music piece	1. The metaphor is valid.	1. The metaphor brings with it all kinds of nuances that only confuse people more. 2. The metaphor is incomprehensible / complicated because of the many outcomes. 3. The metaphor does not illustrate the quantum aspect enough, because the musician can choose what he is going to play (in a quantum measurement we cannot choose what the outcome of the measurement will be). 4. The metaphor is worded too unclearly. 5. The metaphor is too specific, which means that it only appeals to the imagination of a limited number of people.
Entanglement		

Metaphor	Positive	Negative
A pair of dice	1. The metaphor illustrates that the outcome is not known in advance. 2. The metaphor illustrates that a 'measurement' is performed on one part of the entangled state which determines the state of the other part. 3. The metaphor illustrates the probabilistic collapse of the wave function of an entangled state. 4. The metaphor illustrates the 'random' character. 5. The metaphor illustrates that probability is a description of our knowledge. 6. The metaphor is very simple and precise.	1. The metaphor says that the state of the other die is known "automaticcally", while the states of the two dice are correlated in a way that is not classically possible. 2. The metaphor does not illustrate the superposition part, namely that both particles are in different states at the same time, until it is determined. 3. The metaphor misses the instantaneous.
Two dancers performing a perfectly synchronized dance routine		1. The metaphor implies communication by comparing it to humans, while one of the most common misconceptions about entanglement is that you can communicate faster than the speed of light. 2. The dancers can rehearse the dance in advance, so it is not strange that the dancers dance exactly in (anti)phase, that is routine. People can consciously perform actions and synchronize that. 3. The metaphor is too vague. 4. The metaphor suggests 'spooky action at a distance', which is the most misunderstood aspect of entanglement.

Metaphor	Positive	Negative
A telepathic twin	1. The metaphor uses a much larger distance (other side of the planet). 2. The metaphor has somewhere the idea that there is not necessarily a pre-determined local variable (at least, if we assume free will etc.). 3. The metaphor emphasizes the immediate nature of entanglement (the state of the second is determined immediately).	1. The 'determination' in the mind is disturbing. 2. The metaphor implies communication by comparing it to people, while one of the most common misconceptions about entanglement is that you can communicate faster than the speed of light. 3. Suggesting telepathy is not ideal. 4. The metaphor suggests 'spooky action at a distance', which is the most misunderstood aspect of entanglement. 5. Two people can consciously perform actions and then synchronize them. 6. The element of chance is missing where a measurement in one place projects the entire quantum entangled system from an 'indeterminate state' to a combined fixed final state.
Two compass needles that always point in opposite directions	1. The metaphor is intuitively clearest because the action does not come from within, but is commanded externally.	1. The state is always visible and so there is a kind of analogue state. 2. The compasses could still be linked via a magnetic field. 3. The metaphor describes a kind of non-existent correlation that is not quantum mechanical, but also not classical. 4. The metaphor suggests 'spooky action at a distance', which is the most misunderstood aspect of entanglement. 5. Entanglement cannot be used to cause changes at a distance, like a compass needle that you turn north.

Metaphor	Positive	Negative
Two clocks with perfectly synchronized second hands	1. The metaphor is nice. 2. The metaphor is intuitively the clearest, because the action does not come from within, but is externally ordered.	1. This gives all sorts of issues with the theory of relativity. 2. The time in both clocks is a very clear local variable, and therefore resembles most 'normal' classical correlation. The state is always visible and therefore there is a kind of analogue state. 3. The metaphor describes a kind of non-existent correlation that is not quantum mechanical, but also not classical. 4. The superposition is missing. 5. If two particles are entangled, one of the particles can still be adjusted independently of the other by means of, in jargon, a "local transformation". What changes is the correlation. Hence, an active change on one particle influences the other particle does not apply. 6. The metaphor suggests 'spooky action at a distance', which is the most misunderstood aspect of entanglement. 7. Entanglement cannot be used to cause changes at a distance, like changing the time of a clock.

A4.6 Tables for the mediation analyses

Table A19

The indirect, component (path a and b), direct (path c′) and total effects from the mediation analyses with perceived comprehension (PC) as a mediator. The contrasts used are: 1 vs. 2 = control – non-metaphorical and 1 vs. 3 = control – metaphorical. 'Cogn.' refers to cognition.

Non-metaphorical – Control, PC as mediator								
Type	Effect	Estimate	SE	Lower	Upper	β	z	p
Indirect	1 vs. 2 ⇒ PC ⇒ Affect	-0.13	0.04	-0.21	-0.06	-0.07	-3.64	$<$ .001
	1 vs. 2 ⇒ PC ⇒ Cogn.	-0.12	0.03	-0.19	-0.05	-0.06	-3.52	$<$ .001
Path a	1 vs. 2 ⇒ PC	-0.32	0.09	-0.48	-0.15	-0.12	-3.73	$<$ .001
Path b	PC ⇒ Affect	0.42	0.02	0.39	0.46	0.55	21.33	$<$ .001
	PC ⇒ Cogn.	0.38	0.02	0.33	0.42	0.46	16.48	$<$ .001
Path c'	1 vs. 2 ⇒ Affect	0.09	0.05	-0.01	0.21	0.05	1.76	0.079
	1 vs. 2 ⇒ Cogn.	0.04	0.06	-0.09	0.17	0.02	0.65	0.519
Total	1 vs. 2 ⇒ Affect	-0.04	0.07	-0.17	0.09	-0.02	-0.58	0.565
	1 vs. 2 ⇒ Cogn.	-0.08	0.07	-0.22	0.06	-0.04	-1.11	0.266
Metaphorical – Control, PC as mediator								
Type	Effect	Estimate	SE	Lower	Upper	β	z	p
Indirect	1 vs. 3 ⇒ PC ⇒ Affect	-0.12	0.04	-0.20	-0.05	-0.06	-3.37	$<$ .001
	1 vs. 3 ⇒ PC ⇒ Cogn.	-0.11	0.03	-0.18	-0.05	-0.05	-3.28	0.001
Path a	1 vs. 3 ⇒ PC	-0.29	0.08	-0.46	-0.13	-0.11	-3.41	$<$ .001
Path b	PC ⇒ Affect	0.42	0.02	0.39	0.46	0.55	21.33	$<$ .001
	PC ⇒ Cogn.	0.38	0.02	0.33	0.42	0.46	16.48	$<$ .001
Path c'	1 vs. 3 ⇒ Affect	0.01	0.05	-0.10	0.12	0.01	0.22	0.826
	1 vs. 3 ⇒ Cogn.	-0.02	0.06	-0.14	0.10	-0.01	-0.38	0.708
Total	1 vs. 3 ⇒ Affect	-0.11	0.07	-0.24	0.01	-0.06	-1.70	0.089
	1 vs. 3 ⇒ Cogn.	-0.13	0.07	-0.26	0.00	-0.06	-1.96	0.050

Note. Indirect = Path a * Path b, Total = Indirect + Path c', z-statistic = Estimate / SE. Betas are completely standardized effect sizes.

Table A20

The indirect, component (path a and b), direct (path c') and total effects from the mediation analyses with actual comprehension (AC) as a mediator. The contrasts used are: 1 vs. 2 = control – non-metaphorical and 1 vs. 3 = control – metaphorical. 'Cogn.' refers to cognition.

Non-metaphorical – Control, AC as mediator								
Type	Effect	Estimate	SE	Lower	Upper	β	z	p
Indirect	1 vs. 2 ⇒ AC ⇒ Affect	0.15	0.02	0.11	0.19	0.07	6.91	$<$ .001
	1 vs. 2 ⇒ AC ⇒ Cogn.	0.15	0.02	0.11	0.20	0.07	6.39	$<$ .001
Path a	1 vs. 2 ⇒ AC	0.43	0.05	0.33	0.54	0.26	8.22	$<$ .001
Path b	AC ⇒ Affect	0.34	0.03	0.27	0.40	0.28	10.26	$<$ .001
	AC ⇒ Cogn.	0.35	0.04	0.27	0.42	0.27	9.40	$<$ .001
Path c'	1 vs. 2 ⇒ Affect	-0.18	0.07	-0.31	-0.05	-0.09	-2.71	0.007
	1 vs. 2 ⇒ Cogn.	-0.23	0.07	-0.37	-0.09	-0.11	-3.32	$<$ .001
Total	1 vs. 2 ⇒ Affect	-0.04	0.07	-0.17	0.09	-0.02	-0.57	0.566
	1 vs. 2 ⇒ Cogn.	-0.08	0.07	-0.22	0.06	-0.04	-1.11	0.266
Metaphorical – Control, AC as mediator								
Type	Effect	Estimate	SE	Lower	Upper	β	z	p
Indirect	1 vs. 3 ⇒ AC ⇒ Affect	0.10	0.02	0.07	0.14	0.05	5.77	$<$ .001
	1 vs. 3 ⇒ AC ⇒ Cogn.	0.11	0.02	0.07	0.15	0.05	5.65	$<$ .001
Path a	1 vs. 3 ⇒ AC	0.31	0.05	0.21	0.40	0.19	6.32	$<$ .001
Path b	AC ⇒ Affect	0.34	0.03	0.27	0.40	0.28	10.26	$<$ .001
	AC ⇒ Cogn.	0.35	0.04	0.27	0.42	0.27	9.40	$<$ .001
Path c'	1 vs. 3 ⇒ Affect	-0.22	0.07	-0.35	-0.09	-0.11	-3.31	$<$ .001
	1 vs. 3 ⇒ Cogn.	-0.24	0.07	-0.37	-0.11	-0.11	-3.55	$<$ .001
Total	1 vs. 3 ⇒ Affect	-0.11	0.07	-0.24	0.02	-0.06	-1.66	0.097
	1 vs. 3 ⇒ Cogn.	-0.13	0.07	-0.27	0.00	-0.06	-1.94	0.053

Note. Indirect = Path a * Path b, Total = Indirect + Path c', z-statistic = Estimate / SE. Betas are completely standardized effect sizes.