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Similar representation of names and faces in the network for person perception.

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Abstract:	Person-knowledge encompasses the diverse types of knowledge we have about other people. This knowledge spans the social, physical, episodic, semantic & nominal information we possess about others and is served by a distributed cortical network including core (perceptual) and extended (non-perceptual) subsystems. This cortical system is tightly linked to the perception of faces and the extent to which cortical knowledge-access processes are independent of perception is unclear. In this study, participants were presented with the names of famous people and performed ten different semantic access tasks drawn from five cognitive domains (biographic, episodic, nominal, social and physical). We used representational similarity analysis, adapted to investigate network-level representations (NetRSA) to characterise the inter-regional functional coordination within the non-perceptual extended subsystem across access to varied forms of person-knowledge. Results indicate a hierarchical cognitive taxonomy consistent with that seen during face-processing and forming the same three macro-domains: socio-perceptual judgements, episodic-semantic memory and nominal knowledge. The coordination across regions was largely preserved within elements of the extended system associated with internalised cognition but differed in prefrontal regions. Results suggest the elements of the extended system work together in a consistent way to access knowledge when viewing faces and names but that coordination patterns also change as a function of input-processing demands.
Suggested Reviewers:	Paul Downing p.downing@bangor.ac.uk Prof Downing's work investigates the organisation of visual processes in the mind and brain, using fMRI with a particular focus on understanding how we perceive other people. The current manuscript fits well with Prof Downing's research interests and expertise.
	Ingrid Olson iolson@temple.edu Dr. Ingrid Olson's work studies semantic memory, decision making, social cognition, and the intersection of these processes using fMRI and network modeling. Our manuscript fits her research interests and expertise
Opposed Reviewers:	

1. Cover Letter

Dear Editor,

We would like to submit our article, entitled "Similar representation of names and faces in the network for person perception" to be considered for publication in your journal.

In this article we investigate the mechanisms by which name-cued access to person-knowledge is enacted by the extended system for face-perception. Building on previous research that used multivariate analyses (network-level representational similarity analysis; NetRSA) to investigate cognitive and regional person-knowledge taxonomies during face-cued access. In this article we compare brain activity patterns measured using fMRI during face- and name- cued access to person knowledge to demonstrate the stability in the way person knowledge is represented. Despite the change in the way this information is cued (viewing faces vs. reading names) relationships between different person-knowledge domains (physical, social, biographical, episodic and nominal knowledge) remains largely stable, evoking reliably similar patterns across the extended system regions, previously associated with face-cued knowledge representation. Additional analysis of regional taxonomy suggest that this stability may be accomplished by partial reconfiguration of the network - with frontal regions (IFG and OFC) changing their coordination profiles to maintain representational stability across modalities.

The topic addressed in this manuscript is of interest for a broad audience of researchers investigating face perception, social cognitive and neural bases of knowledge representation. For these reasons we ask you to consider our manuscript for publication in Neuroimage.

Sincerely,

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1 **Similar representation of names and faces in the network for person**

2 **perception.**

3

4 **Abstract**

5

6 Person-knowledge encompasses the diverse types of knowledge we have about other people.

7 This knowledge spans the social, physical, episodic, semantic & nominal information we possess

8 about others and is served by a distributed cortical network including core (perceptual) and

9 extended (non-perceptual) subsystems. This cortical system is tightly linked to the perception of

10 faces and the extent to which cortical knowledge-access processes are independent of

11 perception is unclear. In this study, participants were presented with the names of famous people

12 and performed ten different semantic access tasks drawn from five cognitive domains

13 (biographic, episodic, nominal, social and physical). We used representational similarity analysis,

14 adapted to investigate network-level representations (NetRSA) to characterise the inter-regional

15 functional coordination within the non-perceptual extended subsystem across access to varied

16 forms of person-knowledge. Results indicate a hierarchical cognitive taxonomy consistent with

17 that seen during face-processing and forming the same three macro-domains: socio-perceptual

18 judgements, episodic-semantic memory and nominal knowledge. The coordination across

19 regions was largely preserved within elements of the extended system associated with

20 internalised cognition but differed in prefrontal regions. Results suggest the elements of the

21 extended system work together in a consistent way to access knowledge when viewing faces and

22 names but that coordination patterns also change as a function of input-processing demands.

23

24 **Keywords: Person Knowledge, fMRI, Cortical Network, Face Perception, Representational**

25 **Similarity Analysis.**

26

27 **Introduction**

To efficiently interact with conspecifics, we need to not only recognise the identity of the individual, but also to access the diverse kinds of information we associate with them (memories, facts, social information, names). Such person-related information about a familiar individual can be accessed both when we see their face and when we read their name. However, the extent to which the neural mechanisms underlying this process differ between face-viewing and name-reading remain uncertain.

Originally conceptualised as a face-processing system, the network of brain regions thought to underlie perceiving and knowing about others has been extensively studied (Fairhall & Ishai, 2007; Gobbini & Haxby, 2007; Haxby et al., 2001; Haxby, Hoffman, & Gobbini, 2000). This distributed cortical network has been divided into core and extended systems (Haxby et al., 2000). The "core system" consists of occipital and fusiform face areas (OFA, FFA; Gauthier et al., 2000; Kanwisher, McDermott, & Chun, 1997) and posterior superior temporal sulcus (pSTS) and is primarily involved in perceptual processing. The extended system is activated more when viewing familiar than unfamiliar faces and consists of regions associated with non-perceptual person-related cognition. These regions include the inferior frontal gyrus (IFG), orbitofrontal cortex (OFC), amygdala, ventromedial and dorsomedial prefrontal cortices (vmPFC, dmPFC), anterior temporal lobe (ATL), angular gyrus (AG), precuneus, and potentially—the recently identified, face-selective anterior temporal face patch (ATFP; Gobbini & Haxby, 2007; Rajimehr, Young, & Tootell, 2009; Tsao, Moeller, & Freiwald, 2008; Von Der Heide, Skipper, & Olson, 2013).

The role of the extended system in access to information about others in the absence of faces is less well understood. While elements of the core system are not selectively activated by person-related name stimuli (Bi, Wang, & Caramazza, 2016), some regions of the extended system do exhibit a preference for person-related word stimuli. The names of famous people selectively activate components of the extended system compared to common-nouns referencing face parts (Wang, Peelen, Han, Caramazza, & Bi, 2016) and names of famous places (Fairhall, Anzellotti, Ubaldi, & Caramazza, 2014). Regions of the extended system are also selectively activated when participants access information about general kinds of people (e.g. "professions"; Fairhall & Caramazza, 2013) or when processing more complex, sentence-level, stimuli involving people (Rabini, Ubaldi, & Fairhall, 2021). These findings indicate at least some

commonality in the representation of person-knowledge for face- and name-cued cognition. However, it remains uncertain how name and face stimuli alter the access to person-related information in the extended system and whether these differences (if they exist) would be reflected in regional changes, or more diffuse differences in regional coordination.

In a recent fMRI study we showed that, when viewing faces and accessing varied forms of information about the pictured individual, the diverse kinds of person-knowledge are enabled by the coordinated interactions between regions (Aglinskas & Fairhall, 2020). We observed relative rather than absolute variations in regional preferences when nominal, episodic, biographical, social and physical knowledge was accessed. These variations were utilised in a multivariate analysis (NetRSA) that exploited regional and cognitive profiles across nodes of the face-processing system. When viewing famous faces, this approach revealed a hierarchical cognitive taxonomy based on the cognitive tuning profiles of different network nodes, which grouped physical with social knowledge, biographic with episodic knowledge, and separately, nominal knowledge. At the same time, comparing regional coordination profiles across varied forms of information access, we were able to decompose the network into three subcomponents that reliably work together to accomplish cognitive goals: a perceptual-prefrontal subsystem (core regions, OFC, IFG), an intrinsic/default mode network (DMN) subsystem (precuneus, vmPFC, lateral ATL, angular gyrus) and an anterior ventral subsystems (ATFP, amygdala). The NetRSA approach allowed us to characterise both the relationship between different forms of person-knowledge and the coordination between different brain regions across varied forms of cognitive access.

In the present study, we leverage this approach to investigate whether the cortical implementation of access to person-knowledge in the extended system is reshaped when knowledge is accessed via words instead of faces. While reading names of famous people, participants recalled ten different types of knowledge spanning five domains of person-knowledge (social, physical, episodic, biographical & nominal). Through NetRSA, we exploit the rich information present in the regional response profile across access to varied forms of person-related information to characterise the relationships between these processes. We predict that if cognitive processes are consistent across modalities, we will observe a preserved relationship

1 between different tasks/cognitive domains across modalities while alterations in this

2 organisation will indicate reorganisation across modalities.

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Methods

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Participants

7 Thirty-one participants took part in this study (mean age M = 24.74, SD = 3.13). All participants

8 had normal or corrected to normal vision and no history of neurological disorders. Procedures

9 were approved by the University of Trento Ethical committee. Participants gave written informed

10 consent and were compensated for their time. Seven participants were excluded prior to

11 analysis. Two of these participants did not complete the experiment due to technical issues with

12 the stimulation computer and data from five participants were excluded due to excessive head-

13 motion in the scanner. The final subject pool consisted of 24 subjects.

14

Stimuli

16 Stimuli were 40 names of recognisable famous people (politicians, actors, athletes or business

17 people). First and last names were presented in large font on separate lines. Mean name length

18 was M = 12.15, SD = 2.59 letters. For monuments control task, stimuli were written names of

19 familiar places presented in Italian ("Notre Dame", "Piramidi di Ghiza", etc.). Person names and

20 monument names did not differ in overall length (t(78) = 0.30,p = 0.768, independent sample t-

21 test).

22

Task

24 Each experimental block started with a 4s instruction screen specifying the task, followed by a 6s

25 fixation cross. After that a name was presented for 0.5s followed by 2s of fixation cross during

26 which subjects provided a response via a button box. Within each 8-trial block, participants were

27 instructed to respond to a question from one of the five categories of person-knowledge:

28 episodic memories, semantic knowledge, social judgments, nominal knowledge and physical

29 knowledge. For each category, we chose two different probe questions that required access to

1   each kind of knowledge (totalling ten experimental tasks; see Figure 1 and Table 1). In addition,

2   there were two 1-back matching control tasks with either names of people or monuments. The

3   experiment consisted of five runs (8 min, 42s each). Sixteen blocks were presented in a

4   randomised order (one block for each task plus three repetitions each of face and monument 1-

5   back control blocks). Participants responded via a button box. For 9/10 tasks the rating scale was

6   a 1-4 Likert scale. For the occupation question ("what is this persons' occupation"), answer

7   choices had predefined categories (1 = actor or TV presenter, 2 = singer or musician, 3 = politician

8   or sportsman, 4 = other or none of the above). Prior to scanning, participants practiced answering

9   experimental questions on a different set of famous people repeating each question for five
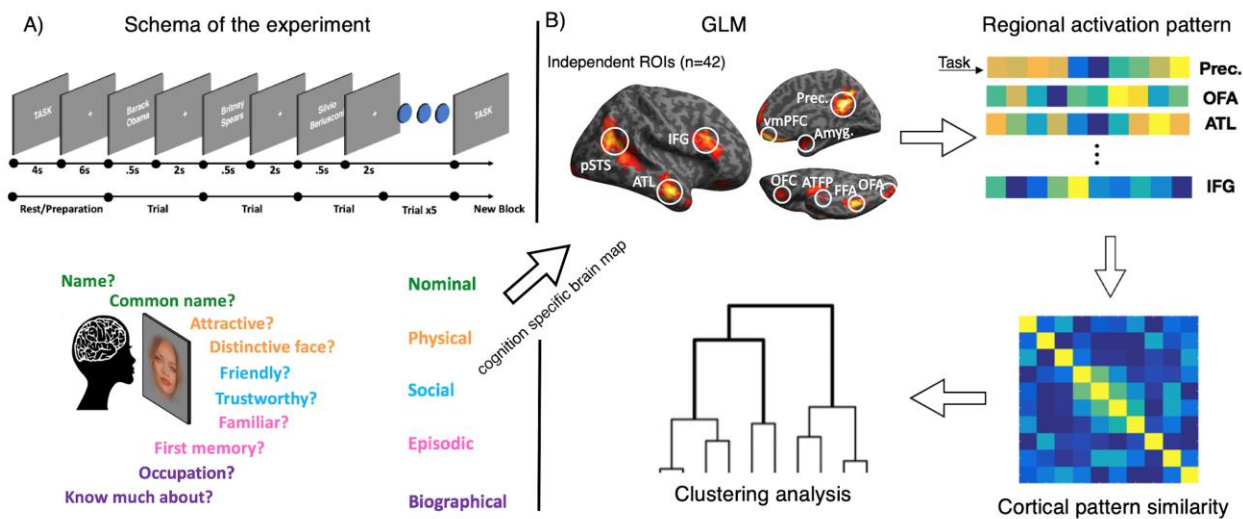
10   trials.

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13   *Figure (1). Experimental and data analysis procedures. A) Schematic of the fMRI experiment.*

14   *B) Analysis schematic: task specific response estimates (beta values) for each task were extracted*

15   *from independently defined, face-selective ROIs. This resulted in a 10 value vector (each value*

16   *representing response magnitude for each person-knowledge task) for each ROI. Response*

17   *vectors were then correlated to obtain task-similarity and ROI-similarity matrices. ROI similarity*

18   *matrices were entered into a clustering analysis to find groups of regions similarly responding*

19   *across tasks. Task similarity matrices were entered into a clustering analysis to find groups of*

20   *tasks sharing common neural signatures.*

1   Table 1. Task description. For each of the five person-knowledge domains investigated, we

2   choose two representative probe questions, totalling ten experimental conditions.

Knowledge Category	Task Cue	Participant Instructions	Answer Choices
Nominal	Common name	How common is this person's first name?	Likert scale (1-4)
	Common surname	How common is this person's last name?	Likert scale (1-4)
Physical	Attractive	How attractive do you find this person?	Likert scale (1-4)
	Distinctive	How distinctive is this person's face?	Likert scale (1-4)
Social	Friendly	How friendly is this person?	Likert scale (1-4)
	Trustworthy	How trustworthy is this person?	Likert scale (1-4)
Episodic	Familiar	How familiar is this person to you?	Likert scale (1-4)
	First memory	For how long have you known this person?	Likert scale (1-4)
Biographical	How many facts	How many facts can you recall about this person?	Likert scale (1-4)
	Occupation	What is this person's occupation?	Predefined categories (see "task")

3

Data Acquisition

Participants were scanned at the Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy. Data was collected using Bruker BioSpin MedSpec 4T, with 8-channel phased-array head coil. Five runs of 209 echo-planar volumes, consisting of 34, AC-PC aligned axial slices were acquired while participants performed the task (FOV = 64mm x 64mm, TR = 2.5s, TE = 33, FA = 73°). Voxel size was 3x3x3mm with a 1mm gap. In addition to functional data, a whole brain T1 MPRAGE anatomical image was acquired (whole brain (FOV = 256x224, 176 1mm axial slices).

Data Analysis

Data were pre-processed with SPM12. Functional images were realigned to account for motion, grey matter segmented, warped into MNI space and smoothed with an 8mm FWHM kernel. Subject specific response estimates (beta weights) were derived by fitting a general linear model (GLM) to the data. 12 regressors (ten experimental tasks, two control tasks) were included as explanatory variables. Six motion parameters from the re-alignment procedure were included as regressors of no interest.

Regions of Interest

Regions of interest (ROIs) were selected from an independent (N=42) experiment, to allow unbiased ROI analysis. In the localiser experiment, participants performed a 1-back matching task with 12 second blocks of famous faces, common animals or common objects. The contrast faces > animals+tools was used to identify face selective peaks. To mediate anatomical specificity and signal strength, we drew 7.5mm radius spheres around the chosen face-selective coordinates (diameter = 5 voxels, voxel size $3mm^3$); We then extracted the mean beta value from voxels within those ROIs that were significantly active at $p < 0.001$ (contrast faces > animals+tools, see Table 2 for location and extent). Activity during the experimental (person-knowledge) tasks did not factor into the localisation procedure.

1   To baseline the cognitive response with respect to perceptual effects elicited by reading

2   names, within each region, the activation magnitude during the control condition (1-back famous

3   name matching task) was subtracted from task activation.

4

5

6   Table 2. ROI sphere centre coordinates. Peak MNI coordinates for regions active in the localiser

7   experiment (N=42) and ROI sizes in voxels after thresholding.

8

Region	Hemisphere	X	Y	Z	ROI Size
Precuneus	Medial	3	-52	29	81
IFG	Left	39	17	23	44
	Right	-36	20	26	38
ATL	Left	-60	-7	-19	69
	Right	57	-7	-19	81
Amygdala	Left	-21	-10	-13	62
	Right	21	-7	-16	59
dmPFC	Medial	6	59	23	59
vmPFC	Medial	3	50	-19	66
OFC	Left	33	35	-13	58
	Right	-33	35	-13	27
ATFP	Left	33	-10	-40	39
	Right	-36	-10	-34	24
	Left	-48	-67	35	68

Angular Gyrus	Right	42	-64	35	57

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6 **Multivariate Analyses & RSA Models**

7 Regional responses were averaged across voxels within each ROI, separately for each task.

8 Average ROI responses to each task were pairwise correlated to obtain a ROI dissimilarity matrix

9 (1-r), which was then entered into Ward hierarchical agglomerative clustering (Ward, 1963). For

10 task similarity analysis the ROI response matrix was transposed before correlating such that the

11 similarity matrix consisted of task dissimilarity across ROIs (Figure 1b).

12 To build models of task and ROI similarity, an almost identical experiment was performed

13 with an independent group of subjects (N=20) using faces instead of names as stimuli ("face

14 experiment" Aglinskas & Fairhall, 2020). Task and ROI similarity matrices from the face

15 experiment (figures 4 & 5 in Aglinskas & Fairhall, 2020) were used as empirical RSA models, and

16 compared with their respective similarity structures in the current experiment, using a standard

17 RSA model comparison framework (Kriegeskorte, Mur, & Bandettini, 2008).

18

19 # Results

20

21 **Behavioural Results**

22 Average reaction time (RT) across all tasks was M = 630msec, SD = 122msec. Participants

23 responded the fastest during attractiveness judgements (M = 577msec SD =120msec), and

24 slowest during "last name" task (693msec SD = 176msec). Reaction times differed across ten

25 tasks $F_{(4.7,84.6)} = 4.04$, p = .003 (Greenhouse-Geisser corrected), but critically, were balanced

26 across task domains $F_{(4,72)} = 1.83$, p = .132. To verify participants' knowledge about famous

27 people used as stimuli, we analysed their in-scanner behavioural responses during "familiarity"

1   and "occupation" tasks (Table 1). When asked about familiarity, M = 87% SD = 8.2% of

2   participants indicated at least some degree of familiarity with the stimulus person (between 3 -

3   "little" to 1 - "very much"). Participants correctly identified the occupation of M = 82%, SD = 15%

4   of people, indicating high levels of knowledge about the people presented.

5

6   **Overall response to name-cued person-knowledge.**

7   To ensure that accessing person-knowledge during word reading produced activations broadly

8   consistent with face-cued person-knowledge access - we performed a whole brain analysis,

9   collapsing across task domains. The contrast of all person-knowledge tasks > 1-back famous name

10   matching (voxel threshold $p < .001$, cluster threshold $p < .05$, family-wise error corrected)

11   revealed an expected cluster of activations, broadly consistent with the extended system for face

12   perception (Table 3). These regions include extended system regions associated with intrinsic

13   cognition: Precuneus (PREC), Angular Gyri (AG), dorsomedial (dmPFC) and ventromedial

14   prefrontal cortices (vmPFC) and left anterior temporal lobe (ATL). Name-cued person-knowledge

15   tasks also recruited a broad cluster of activations over the left prefrontal cortex including the

16   inferior frontal gyrus (IFG) and lateral orbitofrontal cortex (OFC).
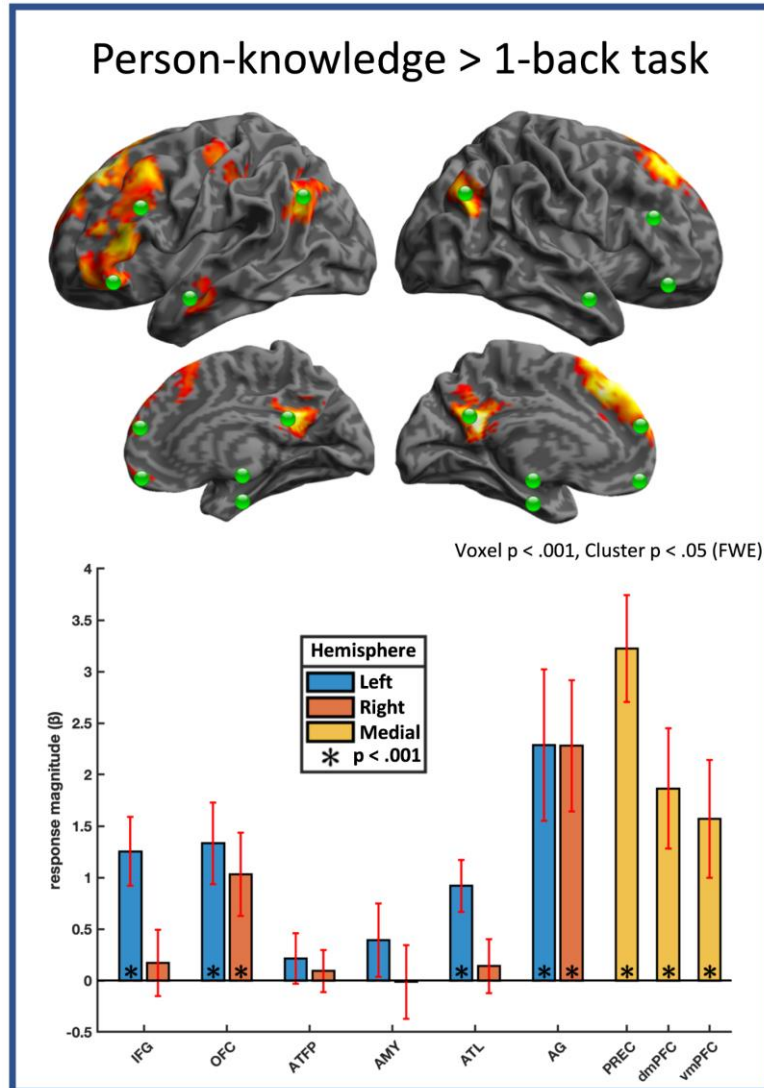
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Figure 2. Name-cued access to person-knowledge. A) Whole brain map showing regions more active during person-knowledge tasks than 1-back famous person name matching task. Regions associated with internalised cognition (precuneus, vmPFC, dmPFC, vmPFC, left ATL, bilateral AG, left OFC) are activated. Responses in other key regions active during face-cued person-knowledge retrieval (amygdala, ATFP, right OFC, right ATL) were not significant after cluster correction. Green dots indicate the loci of independent ROIs. B) Independent ROI analysis of face-selective extended system regions' involvement in access to person-knowledge during name reading.

1   *Table 3. Whole brain activations during semantic access (all person-knowledge tasks > 1-back*

2   *name matching). For activation clusters larger than 1000 voxels, we additionally report individual*

3   *peaks spaced more than 30mm apart.*

		Cluster statistics			Peak statistics			
Region	Hemisphere	p (FWE)	extent (voxels)	t	p (FWE)	x, y, z (mm, MNI)		
dmPFC	Medial	< .001	3076	9.60	< .001	-12	32	53
IFG	Left			6.98	< .001	-51	26	11
OFC	Left			6.16	< .001	-39	17	44
PREC	Medial	< .001	541	9.70	< .001	0	-49	26
vmPFC	Medial	0.041	56	5.51	0.003	0	50	-19
ATL	Left	< .001	134	6.00	< .001	-60	-10	-19
AG	Left	< .001	301	7.65	< .001	-45	-61	26
	Right	< .001	266	6.93	< .001	51	-67	35
Precentral g.	Left	< .001	203	5.44	0.005	-36	-19	53
Cerebellum	Left	0.012	74	5.59	0.002	-36	-76	-40
	Right	< .001	441	7.46	< .001	36	-79	-40

4

5   To further investigate person-knowledge representation in these regions, we extracted response

6   magnitudes for each task, from face-selective ROIs defined using an independent dataset (see

7   methods). To assess the overall univariate response during access to person-knowledge (relative

8   to the name matching task), we averaged across all domains of person-knowledge. One-sample

9   t-tests show that multiple face-selective ROIs also respond to name stimuli when person-

10   knowledge is accessed. Medial regions (precuneus, dmPFC, vmPFC) were strongly engaged by

11   person-knowledge demands (all t > 3.59, p < .003), compared to a 1-back matching task. While

1   AG and OFC responded strongly to person-knowledge demands bi-laterally (all t > 3.74, p < .002)

2   - IFG & ATL only showed significant response in the left hemisphere (left hemisphere (t > 4.79, p

3   < .001); right hemisphere (t < .86, p > .36). Anterior temporal face patch (ATFP) regions and the

4   amygdalae were, on average, not responsive to person-knowledge demands (t < 1.92, p > .067;

5   but see next section: cognitive tuning). While ANOVA indicated weak left lateralised effects (main

6   effect of hemisphere: F(1,23)=5.94, p=.023) differences in lateralization across regions did not

7   reach significance (hemisphere by region interaction F(5,115)=1.43, p=.218).

8   These results confirm that some regions of the extended system are recruited during

9   name-cued person-knowledge retrieval. However they do not inform about the potentially

10 different role each region plays in accessing knowledge of different domains (e.g. social

11 knowledge, biographical knowledge etc.). To better understand regional contributions to

12 ensemble function - we now look into differential regional activations across diverse person-

13 knowledge tasks.

14 **Regional cognitive tuning**

15 While some regions are not active compared to the name-matching task when all cognitive

16 domains are averaged, it is possible that the pattern of recruitment across domains of person-

17 knowledge contains information about the cognitive profile of these regions. Next we perform a

18 preliminary evaluation of whether the response in these regions varied across the five cognitive

19 domains.

20   To visualise the graded importance of different cognitive domains within a particular

21 region - we scale each region's domain-specific response, by the total (summed) response across

22 all five domains. While ANOVA in bilateral ROIs revealed a significant 3-way interaction (domain

23 by region by hemisphere f(20,169.6)=2.92, p=.006; Greenhouse-Geisser corrected), for simplicity

24 results are presented collapsed across hemispheres. The variations in regional sensitivity to the

25 different cognitive domains is evident in (Figure 4). Some regions, like the precuneus, respond

26 strongly to all domains (all t > 6.88, all p < .001), while others respond weakly to only some

27 domains (e,g, ATFP). Overall, regions exhibit graded patterns of preference, with most regions

28 being involved in most cognitive domains, and no brain regions being driven by a single cognitive

1 domain. However, subtle patterns can be seen in the variations of loadings of particular domains

2 in different brain regions. Next, we exploit these graded patterns with NetRSA to build up both

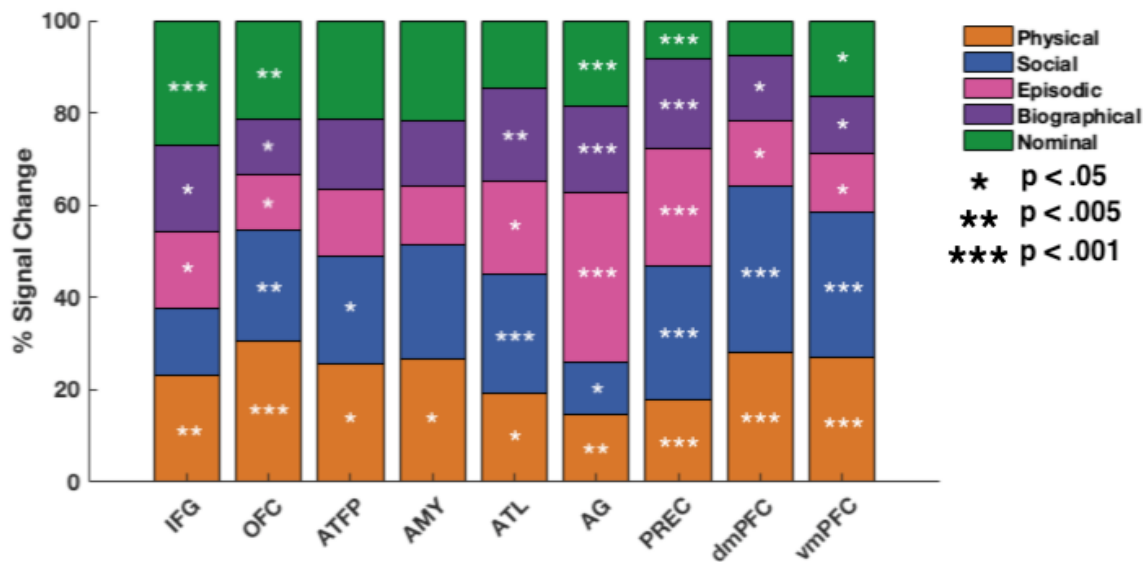3 cognitive tuning and regional coordination taxonomies.

4

5

6 *Figure 4. Regional preference patterns. Percentage of total activation elicited by each cognitive*

7 *domain. Stars denote significance (uncorrected) of regional involvement in a specific person-*

8 *knowledge domain compared to the name-matching baseline condition. Most regions are*

9 *involved in most cognitive domains, and no brain region is driven by a single cognitive domain.*

10 *However subtle patterns can be seen in the variations of loadings of particular domains in*

11 *different brain regions.*

12

13 **Stable cognitive tunings in extended, but not core regions**

14 We next tested whether regional cognitive tunings are consistent during name-cued and face-

15 cued access to person-knowledge. For each region, we used the pattern of activity evoked by the

16 ten person-knowledge tasks during face-cued access (averaged across subjects) as a model, and

17 correlated it to the corresponding regional patterns during name-cued person-knowledge access

18 (for each person individually). Cognitive tasks produce reliably similar patterns during face- and

19 name- cued person-knowledge in the extended system regions (r=.68, t(23) = 6.22 ,p < 0.001).

However, when we repeated this process in core regions, where there was no similarity between patterns during face viewing and name reading r=.20 t(23) = .77,p = 0.448.

Cognitive taxonomy of person-knowledge

A wide range of information can be accessed about people. Knowing which tasks are represented similarly can inform the cognitive structure of person-knowledge. The similarity between these diverse cognitive processes in the human brain can be quantified by the similarities in how they recruit different elements of the extended system. Here we used NetRSA to address the systems-level relationship between the ten tasks probed in this study.

At the most basic level (Figure 5, bottom of the dendrogram tree) - tasks can be seen to group into task-pairs; tasks sampled from the same person knowledge domain (social, physical, episodic, biographical and nominal) produce similar patterns of regions activations and are grouped close together. Higher order clustering (further up the dendrogram tree) reveals relationships not only between tasks, but between task domains. Specifically, biographical and episodic knowledge are more similar to each other than to other tasks. Nominal knowledge forms a distinct cluster - separate from physical and social knowledge tasks, which are grouped together. One exception to this is the distinctiveness task, which clustered tightly with other socio-perceptual judgements in face study, but here seems more closely related to nominal tasks. Multidimensional Scaling (MDS) procedure offers an alternate (two-dimensional) view of task similarity and allows to disambiguate these results. It can be seen in the MDS that the distinctiveness task still shares a substantial amount of pattern similarity with attractiveness and social tasks and is positioned roughly equidistant between nominal and socio-perceptual task clusters.
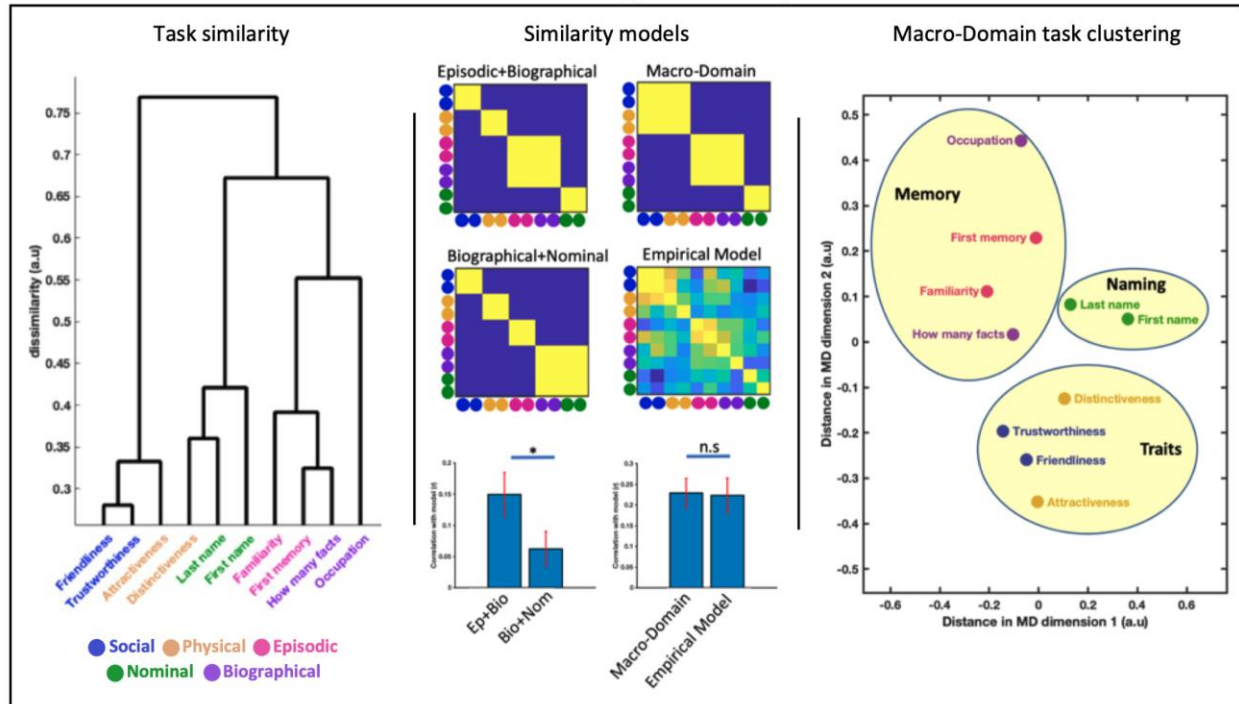
Figure 5. Organization of person-knowledge. Left: Dendrogram plot reflecting the similarity in network activation patterns. Tasks that are linked with short paths (e.g. those of "trustworthiness" and "friendliness") signify that patterns across the extended system ROIs during these tasks are similar. Points far apart (e.g. "occupation" and "attractiveness") mean that these tasks elicit different patterns. Middle: Matrices illustrate hypotheses about cognitive structure expressed as models of expected similarity. Bar graphs show model fit comparisons. Biographical knowledge is represented more like episodic knowledge, than nominal knowledge. The theoretical macro-domain model explains as much variance as the empirical model derived from the face viewing experiment. Right: Multidimensional task similarity structure visualised. MDS plot of task similarity with macro-domain clusters overlaid. Ten cognitive tasks form three groups of cognitions: social and physical trait judgements, tasks involving retrieval of episodic or biographical knowledge, and tasks involving knowledge about names.

Three macro-domains of person-knowledge

Previously we showed that the cortical representation of biographic knowledge was more shared with episodic than nominal knowledge, a grouping that is also apparent for the name data. To formally assess whether this generalises to name stimuli, we contrast models in which

16

biographical knowledge is grouped with episodic, against one in which the former is grouped with nominal. Results show that biographical knowledge is represented more similarly to episodic knowledge (r=.40) than nominal knowledge (r=.19), t(23) = 2.89, p = 0.008.

During face viewing, we observed that cognitive tasks cluster into three macro-domains: socio-perceptual judgements, episodic and biographical knowledge, and nominal knowledge. We explicitly modelled this task grouping [r=.64, t(23) = 6.47, p < .001] and see that it captures as much variance as the average face data model itself, the difference between the macro-domain model and the empirical model was not significant, t(23) = 0.18,p = 0.858. This indicates that the similarity between face and name cued cognitive representation in the extended system can be equivalently captured by this theoretical model.

Regional taxonomy

Interregional coupling across cognitive domains

To better understand how coordinated regional activity encodes diverse kinds of person-knowledge, we look at patterns of similarity in cognitive tuning profiles across regions -- identifying groups of regions responding similarly across tasks. We visualise regional similarity structure by computing a dendrogram, and fit competing RSA models of regional similarity to test hypotheses about network organisation.
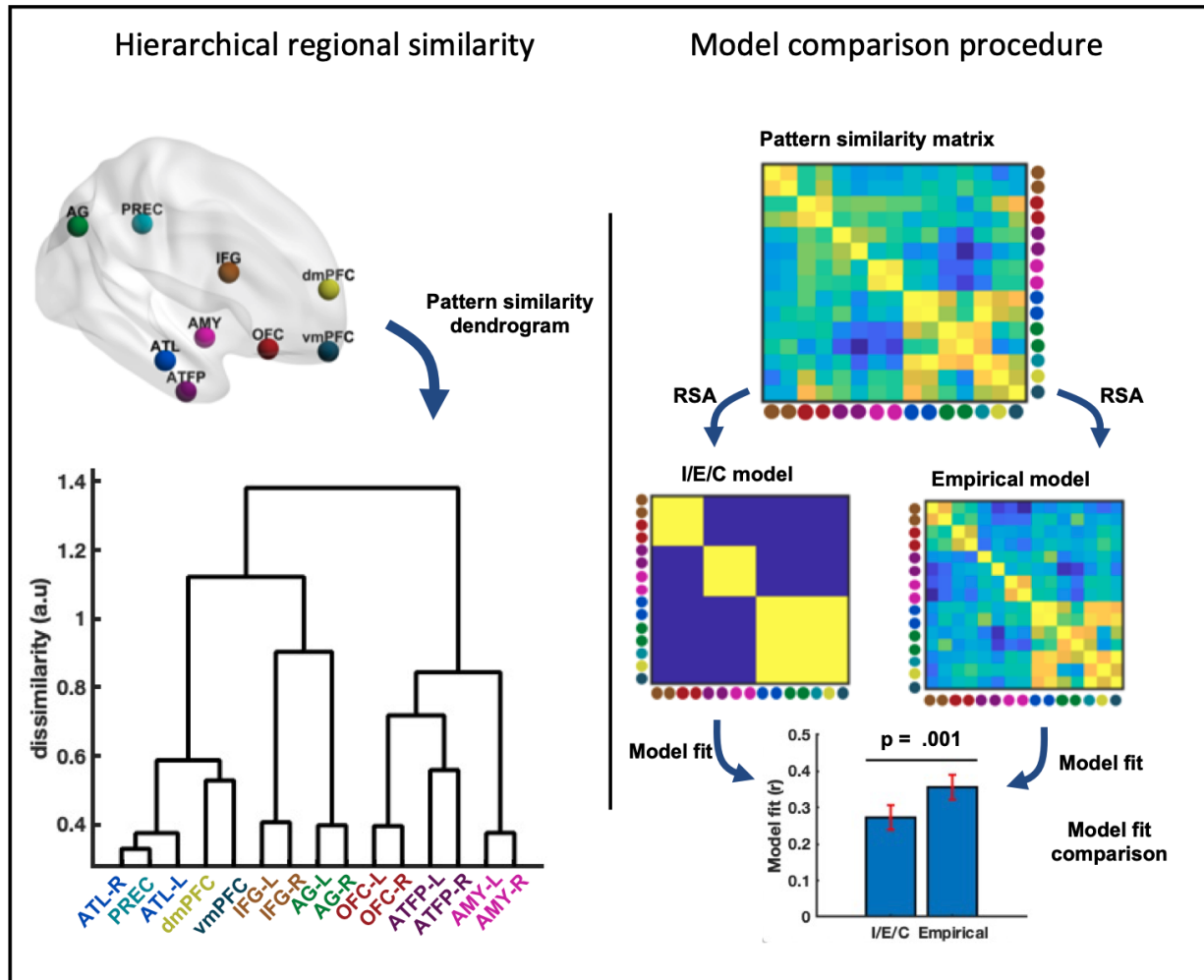
Figure (6). Regional taxonomy of the extended system. Left: Dendrogram showing the clustering of cognitive tuning profiles. First major division in the dendrogram separates internalised cognition regions and IFG from ventromedial regions and OFC. Right: Competing models of regional structure. Average regional similarity during face-cued person-knowledge access ("empirical model") better explains the data than the theoretical model of the tripartite organization into internalised, externalised and control regions ("I/E/C" model).

Hierarchical clustering (dendrogram, figure 6) indicates that, consistent with face-cued access to person information, regions associated with internalised cognitive processes (ATL, precuneus, vmPFC and dmPFC) continue to cluster together, as do ventromedial regions (ATFP, amygdala). The OFC and IFG, which clustered with perceptual regions during face-cued access to person information, exhibit a different regional clustering pattern during name-cued access.

1 Here, the IFG loosely clusters with the AG. During face cued information access, AG was instead

2 relatively loosely linked to intrinsic regions. In contrast, the OFC now clusters with ventromedial

3 ATFP and amygdala.

4   Despite these descriptive changes in clustering, regional coordination in the extended

5 systems remains largely similar between names and faces (consider name-cued pattern-similarity

6 and the face-data model; figure 6). To formally test the degree of convergence across these two

7 modalities, we compared competing models of regional organisation to the observed data. The

8 face-data model captured significant amounts of variance during name reading $t(23) = 10.30$, $p <$

9 .001. While the theoretical model, designed to model the broad tripartite organization into

10 internalised, externalised and control regions ("I/E/C" model) of the extended system seen

11 during face-cued access to person-knowledge, correlated with observed data ($t(23) = 8.24$, $p <$

12 .001), unlike cognitive taxonomy, the theoretical model did not match the empirical model

13 derived from the face data, with the latter capturing significantly more variance ($t(23) = 3.75$, $p =$

14 0.001). This indicates that subtle information beyond these coarse-scale groupings is also shared

15 between words and faces.

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20   **Discussion**

21

22 This study investigated the similarities and differences between cortical substrates underlying

23 access to different variants of person-knowledge when cued by words. We used an RSA approach

24 applied across a network of regions (NetRSA) to characterise the inter-regional functional

25 coordination across access to varied forms of person-knowledge. We contrasted these results to

26 a previous study in which access to person-knowledge was cued by faces (Aglinskas and Fairhall,

27 2020) and observe that: 1) Name-cued access to person-knowledge recruits regions consistent

28 with the face-cued extended system, and that regardless of stimulus modality, these regions are

29 involved in most-all tasks and show relative rather than absolute activation differences across

person-knowledge domains. 2) Extended-system regions form groups of functionally similar units, some having stable functional roles across modalities (internalised cognition and ventromedial regions) while some show flexible coupling depending on stimulus demands (IFG and OFC). 3) Consistent with face-cued access, the pattern of regional coordination across tasks groups cognitive domains into three macro-domains: memory, naming and socio-perceptual judgements.

Regional taxonomy

First, we examined the traditional univariate response for access to person-knowledge (relative to 1-back name matching) in the absence of face stimuli. Access to person knowledge elicited activations in key components of the default mode network: medial PFC, the precuneus and bilateral angular gyri. The left lateral ATL, left IFG and bilateral OFC also showed robust activation during name-cued access to person-knowledge. In contrast, in the right IFG, right ATL and bilateral AMY and ATFP, name cued responses were weak or absent, which on the surface implies that these regions do not play a role in access to person-knowledge in the absence of faces.

However, despite absences of overall increase in activation in some regions, subtle yet systematic variations in response profiles were evident. These variations were used for the multivariate NetRSA approach to quantify the relationship between the response profiles of elements of the extended system. We see that, for all regions, left and right homologues cluster together into functional units. This pattern persists in cases where the overall effect in the left hemisphere region is significant and in the right hemisphere region it is not (IFG, ATL), or when neither regions show a significant overall increase in response relative to 1-back name matching (ATFP). This demonstrates that the varied forms of person-knowledge drive these regions in a consistent way and indicates that they contribute to the retrieval of knowledge about conspecifics even in the absence of an overall response.

As can be seen in figure 4, regional response patterns across cognitive domains show that most regions are involved in most person-knowledge domains, that no regions are responsive to a particular domain, and that there are subtle variations between cognitive tuning across regions.

1   These subtle variations accumulate into hierarchical clusters of inter-regional coordination across

2   tasks: intrinsic, ventromedial and a loose grouping comprising the IFG and angular gyri.

3   The intrinsic subcomponent of the extended system is highly conserved across face- and

4   name-cued access to person-knowledge. This is consistent with the location of these regions in

5   DMN. This set of brain regions is involved in internalised processes that are largely independent

6   of interactions with the outside world (Spreng & Grady, 2010) and are therefore expected to be

7   relatively insensitive to the modality of the simulus. One exception to this pattern was the AG.

8   This region was loosely grouped with the other elements of the intrinsic system during face-cued

9   access to person-knowledge (Aglinskas and Fairhall, 2020). In the present study, we see that this

10   grouping is lost, with the region instead loosely grouping with the IFG. The IFG responds

11   selectively to faces when identity must be extracted from a face but not when a purely perceptual

12   judgement is made, suggesting that this region is involved in identity processing or identity

13   extraction (Ubaldi & Fairhall, 2021). During face-cued access to person-knowledge, the functional

14   profile of the IFG was similar to the functional profiles of core regions, which we attributed to

15   top-down control of perceptual processes (Aglinskas and Fairhall, 2020), as supported by studies

16   showing that TMS stimulation to IFG modulates the response in core regions (Renzi et al., 2013)

17   and findings of common temporal tuning profiles between IFG and core regions (Bortolon,

18   Capdevielle, & Raffard, 2015; Ubaldi & Fairhall, 2020). In the present study, where top-down

19   perceptual face-processing demands are absent, more subtle, non-perceptual aspects and

20   coordinations across tasks may be more apparent, and the relationship between IFG and other

21   regions may become more evident. The reason this leads to the loose coupling between IFG and

22   AG observed here is uncertain. While these regions are commonly active in semantic processes

23   (Binder & Desai, 2011), and AG and dorsolateral prefrontal regions including IFG are associated

24   with processes like memory post-retrieval monitoring (Achim & Lepage, 2005), as well as

25   attentional orienting (Corbetta & Shulman, 2002). The reason for their common coactivation

26   patterns in the present context is uncertain. Like the IFG, the OFC grouped with core perceptual

27   systems during face-cued access. Here, in the absence of these perceptual demands, OFC groups

28   with ventromedial regions, the ATFP and amygdala. This grouping may reflect the role of the OFC

29   in reward processes (Adolphs, 2002; Bortolon et al., 2015) and it's connectivity with limbic

1 systems, such as the amygdala (Baxter & Murray, 2002; Dixon, Thiruchselvam, Todd, & Christoff,

2 2017).

3   The focus of this work was on the preservation of overall regional organisation across

4 face- and name-cued access to person-knowledge. Despite the alterations in clustering of specific

5 regions (IFG and OFC), the theoretic model of regional groupings that best fit the face-cued access

6 data (internalised/externalised/control) (Aglinskas & Fairhall, 2020), continued to robustly

7 capture regional groupings in the name-cued data. At the same time, there was additional

8 information present in the empirical model, suggesting that the commonality between face- and

9 name-cued access to person-knowledge is encoded in finer-grained patterns than this coarse

10 three-cluster model. This means that person-knowledge, as it is shared across face and name

11 cued processing, is best captured in the subtle variations of interregional activity rather than

12 broad functional subdivisions of this network. This, in turn, suggests that person-knowledge does

13 not resolve into "modular" subnetworks - but instead additionally relies on subtle variations in

14 the coordinated activity within and between these subnetworks.

15

16 ***Cognitive taxonomy***

17 When we think about a person we have a range of different knowledge we can access. NetRSA

18 allows us to probe the commonalities and differences in how these forms of knowledge are

19 accomplished within the brain. We observed the relationship between these cognitive domains

20 across the extended system to be highly conserved across name and face cued semantic access.

21 As is the case in face-cued semantic access, cognitive domains were seen to group in memory

22 related processes (semantic, episodic), trait based processes (social, physical) and nominal

23 knowledge. These macro-domains fall broadly within hypothesised domain-specificity

24 boundaries (Spunt & Adolphs, 2017), suggesting that declarative memory (episodic, semantic

25 tasks) and language (nominal tasks) are part of the "cognitive"macro-domain, while facial visual

26 knowledge (physical tasks) and theory of mind (social tasks) are part of the "social" macro-

27 domain. The observation that the macro-domain model explains as much variance as the

28 empirical model shows that differences in the neural representation of these tasks in the

29 extended system can be fully explained by a discrete model without a loss of accuracy. Thus,

unlike the pattern of regional interactions, the relationship between cognitive processes is both conserved across name and face cued access and is equivalently captured by coarse-grained theoretical divisions.

The observed cognitive taxonomy informs the relationships between specific cognitive domains. Social judgements are more similar to perceptual ones than to memory or name related judgements. There is evidence linking social and perceptual processes when related to faces. Attractive people are rated as more trustworthy (Halo effect; Nisbett & Wilson, 1977; Wetzel, Wilson, & Kort, 1981) and parametrically moduled physical facial traits similarly modulate judgement of social traits (dominance, trustworthiness; Oosterhof & Todorov, 2008). In this context, the grouping of social and perceptual cognitive processes in face-cued access is unsurprising. However, the preservation of this grouping in name-cued stimuli (which do not involve face perception) indicates the coupling of these processes that extends beyond the perceptual, potentially reflecting the intrinsic bias in the allocation of social characteristics based on appearance (Wilson & Eckel, 2006).

Semantic knowledge incorporates both factual world knowledge and the meaning contained in words (Tulving, 1972). This prompted us to test whether biographical semantic knowledge relied on neural substrates more similar to those associated with episodic knowledge or with nominal knowledge. Replicating results seen in the face-cued access to person knowledge (Aglinskas & Fairhall, 2020), the link between episodic and semantic forms of memory was seen to be stronger than the link between semantic knowledge and word meaning, suggesting that this form of semantic access is more closely related to other forms of memory than systems that link words to individuals.

Collectively, these results illustrate the capacity of NetRSA to consistently reveal the relationship between different cognitive processes based upon their representations across brain networks. The construction of such cognitive taxonomies is a challenge for cognitive neuroscience. While the similarity between conceptual or semantic processes can, in part, be captured by empirical or computational models (e.g. word embeddings, alexnet, Krizhevsky, Sutskever, & Hinton, 2012; Mikolov, Chen, Corrado, & Dean, 2013), diverse cognitive processes are more challenging to quantify. Traditionally, dissimilarities between different cognitive

processes have to be derived from theory (such as Baddeley & Hitch, 1974; Spunt & Adolphs, 2017). NetRSA provides a highly flexible alternative to uncover the taxonomic structure of different cognitive processes.

Conclusion

The current study addressed the way person-knowledge is represented in the extended system for face-perception. We show that common elements are recruited for both face- and name-cued access to person-knowledge. Multivariate, network-level analysis (NetRSA) revealed that cortical representation of different person-knowledge domains is largely preserved within the extended system regardless of stimulus demands. Diverse types of person-knowledge form three macro-domains sharing common cortical signatures: socio-perceptual information (social and perceptual judgements), memory-related processes (biographical and semantic knowledge) and nominal knowledge. The stability of this cognitive taxonomy is facilitated by the flexible organization of the extended system. Some elements (IFG, OFC) change their coordination patterns, likely to enable the access of stored conceptual content cued by markedly diverse perceptual inputs (faces or names). Conversely - regions associated with internalised cognitive processes were largely agnostic about the modality of presentation. Taken together, these results suggest that the diverse repertoire of person-knowledge, and the ability to access stored information across heterogenous prompts (seeing faces or reading names) - is enabled by the coordinated activity of the extended system regions, rather than relying on any individual region.

Credit authorship contribution statement

1   **Aidas Aglinskas**: Formal analysis, Writing - original draft, Investigation. **Scott L. Fairhall**:

2   Conceptualization, Formal analysis, Writing - original draft, Funding acquisition, Supervision.

3

4   **Data and code availability statement**

5   Binarized ROI mask, domain-specific t-statistic maps and ROI data are freely available on the

6   Open Science Framework (OSF) at the following URL:

7   https://osf.io/ph349/?view_only=df5ded5ea9e84929996aa1644d3e77c9

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Data and code availability statement

Binarized ROI mask, domain-specific t-statistic maps and ROI data are freely available on the Open Science Framework (OSF) at the following URL:

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