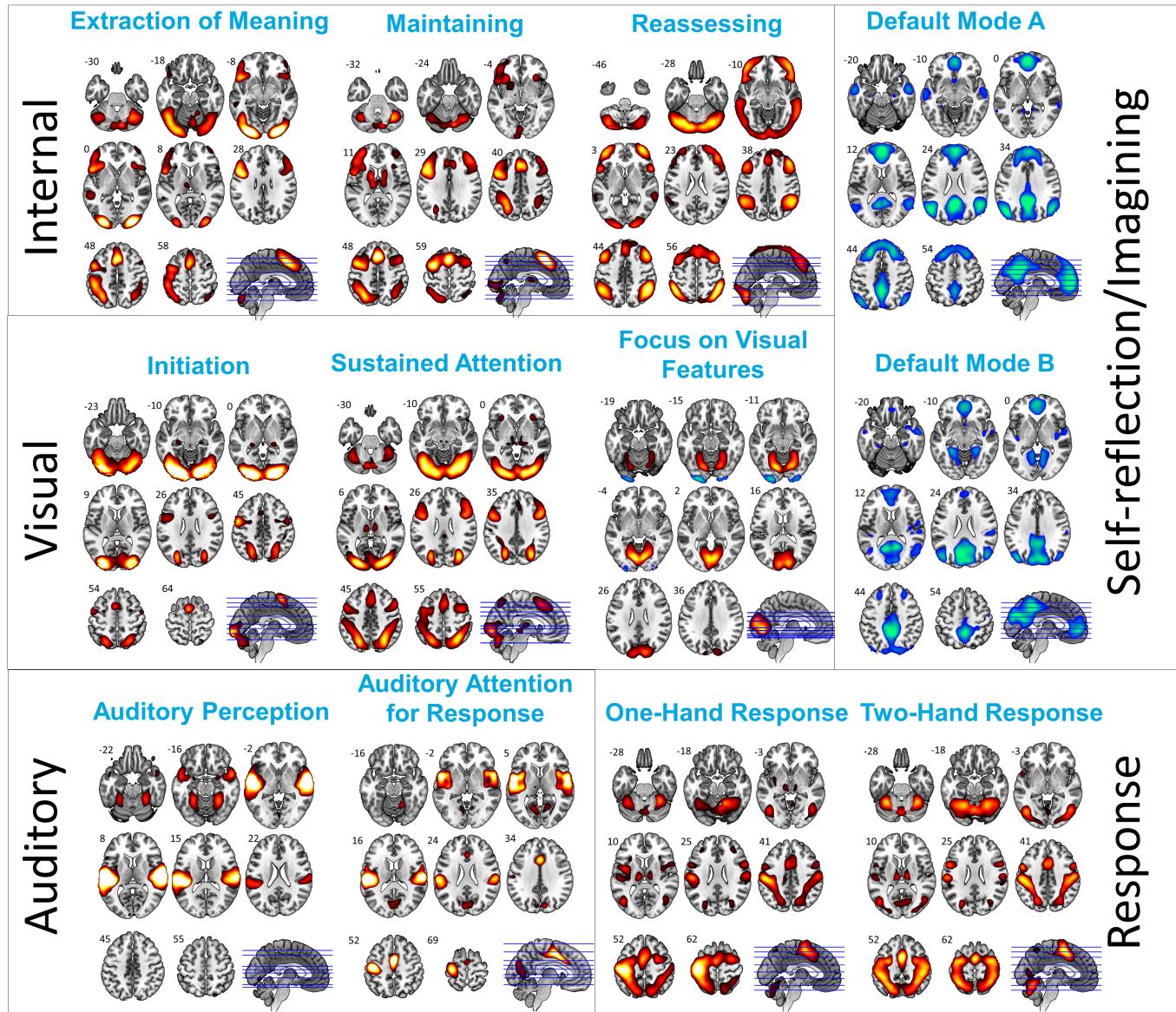


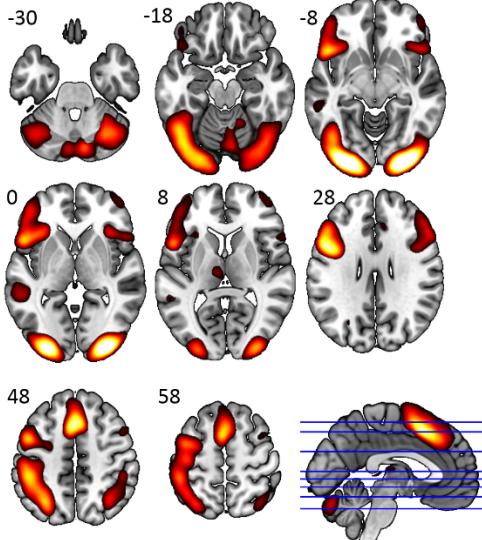
Task-Based Brain Networks Detectable with fMRI
Chantal M. Percival, Hafsa B. Zahid & Todd S. Woodward
Department of Psychiatry, University of British Columbia, Canada

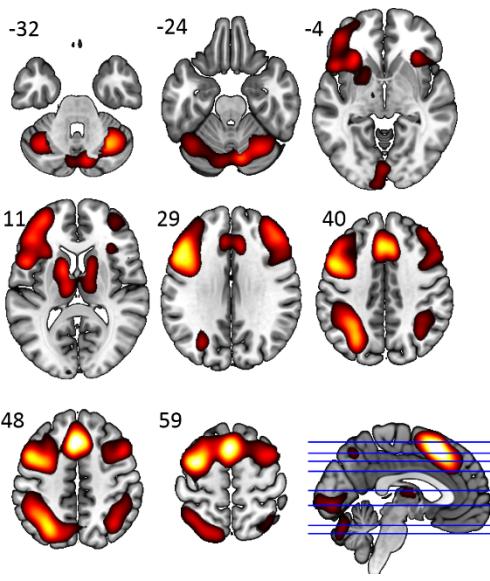
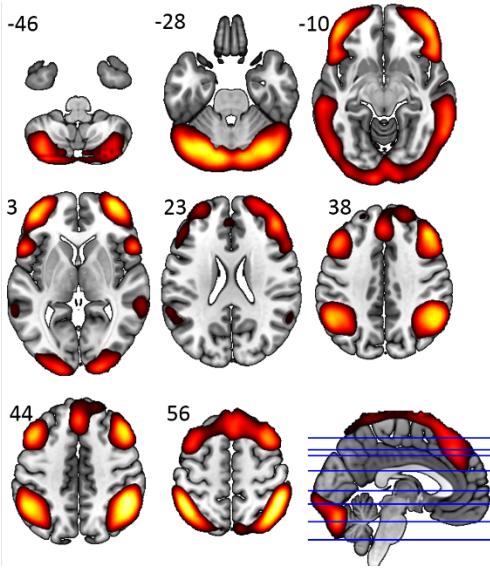


Citation: Percival, C.M., Zahid, H.B., & Woodward, T.S. (2020, November 15). CNoS-Lab/Woodward_Atlas. Zenodo. <http://doi.org/10.5281/zenodo.4274397>

Table 1. fMRI Measures of Cognitive Functions.

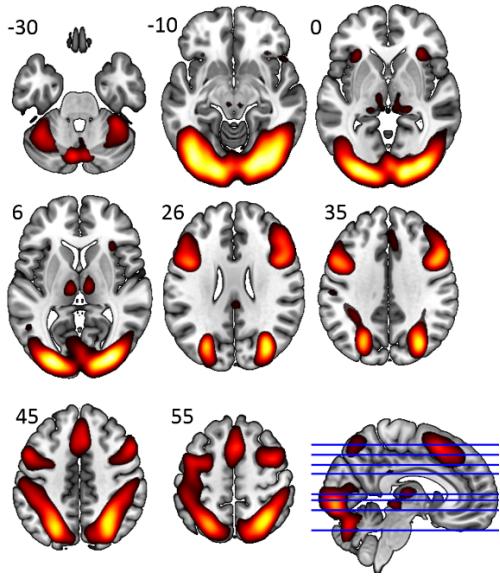
These brain image templates were created by averaging over exemplars of each network. Publications containing these networks are listed below. Any fMRI-CPCA derived network can be automatically classified into those depicted in Figure 1 by a MATLAB-based algorithm that we recently developed, and which will be made available soon. This involved digitizing 20-30 brain slices prototypical of each of the networks, and correlating newly derived networks with those prototype slices, and classifying based on the magnitude of the correlations. Activation in these networks is thought to be capturing the neural correlates of the multiple modular cognitive processes that create an **fMRI-specific, emergent, cognitive super-process**. The functions of these cognitive super-processes are determined by cross-interpreting HDR shapes over the range of tasks eliciting each network.

Networks	Images	Examples
Cognitive processes involved in attending to internal representations		
There are three networks which measure cognitive processes involved in <i>attending to internal representations</i> . The first is <i>Extraction of Meaning</i> , which can be for processing linguistic information when left-lateralized, when it is more active for distant semantic associations [1]. It can also be more bilateral and active for non-verbal information (e.g., faces) [2]. Both have been shown to be impaired in schizophrenia [1, 2]. The second is <i>Maintaining</i> , which shows load-dependence for items in verbal and spatial working memory [3-5], and increased activity when imagine the past or future relative to episodic recall [6]. The third is <i>Reassessing</i> , which involves internal checking, considering that there may have been alternative ways to respond, and internally revising the response. It is more active when disconfirming evidence is presented relative to confirming [7, 8], and this is decreased in delusions (fixed false beliefs) in schizophrenia [8] and delusional ideation in healthy people [7]. It is also more active during incongruent relative to neutral Stroop task performance [4, 5].		
Extraction of Meaning		<u>Component 3</u> Goghari, V.M., Sanford, N., Spilka, M.J. & Woodward, T.S. (2017). Task-related functional connectivity analysis of emotion discrimination in a family study of schizophrenia. <i>Schizophrenia Bulletin</i> , 43(6):1348–1362. PDF <u>Component 3</u> Wong, S.T.S., Goghari, V.M., Sanford, N., Lim, R., Clark, C., Metzak, P.D., Rossell, S.L., Menon, M., & Woodward, T.S. (2020). Functional brain networks involved in lexical decision. <i>Brain and Cognition</i> , 138, doi: 10.1016/j.bandc.2019.103631. PDF

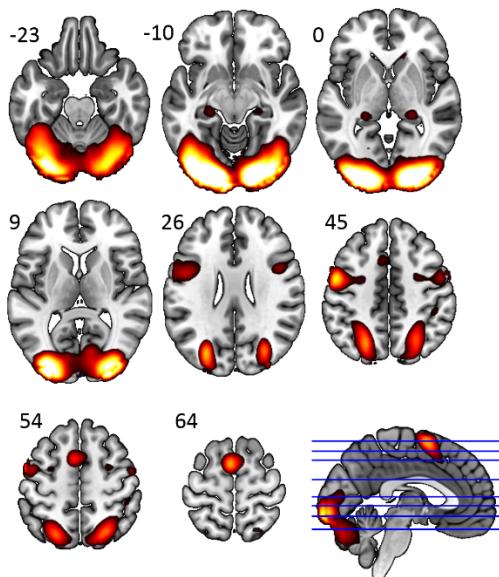
Maintaining		<p><u>Component 2</u> Larivière, S., Lavigne, K.M., Woodward, T.S., Gerretsen, P., Graff-Guerrero, A., & Menon, M. (2017). Altered functional connectivity in brain networks underlying self-referential processing in delusions of reference in schizophrenia. <i>Psychiatry Research: Neuroimaging</i>, 263 (2017): 32–43. PDF</p> <p><u>Component 3</u> Metzak, P.D., Riley, J., Wang, L., Whitman, J.C., Ngan, E.T.C. & Woodward, T.S. (2012). Decreased efficiency of task-positive and task-negative networks during working memory in schizophrenia. <i>Schizophrenia Bulletin</i>, 38(4), 803-813. PDF</p> <p><u>Component 2- Chapter 5</u> Sanford, N. A. (2019). <i>Functional brain networks underlying working memory performance in schizophrenia : a multi-experiment approach</i> (T). University of British Columbia. Retrieved from https://open.library.ubc.ca/collections/ubctheses/24/items/1.0387449</p> <p><u>Component 3- Multi-Experiment</u> Sanford, N., Whitman, J.C. & Woodward, T.S. (2020). Task-Merging for finer separation of functional brain networks in working memory. <i>Cortex</i>, 125, 246-271.doi: 10.1016/j.cortex.2019.12.014. PDF</p>
Reassessing		<p><u>Component 3- Study 2</u> <u>Component 3- Study 3</u> Lavigne, K. M. (2018). <i>Cognitive biases and functional brain networks underlying delusions in schizophrenia</i> (T). University of British Columbia. Retrieved from https://open.library.ubc.ca/collections/ubctheses/24/items/1.0364055</p> <p><u>Component 1</u> Lavigne, K.M., Metzak, P.D., & Woodward, T.S. (2015). Functional brain networks underlying detection and integration of disconfirmatory evidence. <i>NeuroImage</i> 112(2015): 138-151. PDF</p> <p><u>Component 3- Chapter 4 Analysis 3 TSI</u> Sanford, N. A. (2019). <i>Functional brain networks underlying working memory performance in schizophrenia : a multi-experiment approach</i> (T). University of British Columbia. Retrieved from https://open.library.ubc.ca/collections/ubctheses/24/items/1.0387449</p>

Cognitive processes involved in attending to visually presented stimuli.

There are three networks which measure cognitive processes involved in attending to visual stimuli in different ways. The first is *Initiation*, which involves restarting cognitive processing after a break of a few seconds after a set of operations, and peaks very early in the trial [3]. The second is *Sustained Attention*, which is activated when maintaining attention to rapidly presented stimuli [7, 9], and shows increased activity under conditions of more difficult decision making [10]. The third is *Focus on Visual Features (FVF)*, which is activated when details of a scene are important as in spatial working memory [5], but suppressed when it is better to ignore them, for example, when they could impede performance in the Stroop task [4]. This FVF network has been shown to have reduced suppression under the influence of alcohol [11].

Sustained Attention		<p><u>Component 1- Study 2</u> <u>Component 1- Study 3</u> Lavigne, K. M. (2018). <i>Cognitive biases and functional brain networks underlying delusions in schizophrenia</i> (T). University of British Columbia. Retrieved from https://open.library.ubc.ca/collections/ubctheses/24/items/1.0364055</p> <p><u>Component 2</u> Lavigne, K.M., Menon, M., Moritz, S. & Woodward, T.S. (2020). Functional brain networks underlying evidence integration and delusional ideation. <i>Schizophrenia Research</i>, doi:10.1016/j.schres.2019.11.038. PDF</p> <p><u>Component 5</u> Lavigne, K.M., Metzak, P.D., & Woodward, T.S. (2015). Functional brain networks underlying detection and integration of disconfirmatory evidence. <i>NeuroImage</i> 112(2015): 138-151. PDF</p> <p><u>Component 1</u> Woodward, T.S., Tipper, C.M., Leung, A., Lavigne, K.M., Sanford, N., Metzak, P.D. (2015). Reduced functional connectivity during controlled semantic integration in schizophrenia: A multivariate approach. <i>Human Brain Mapping</i>, 36: 2948-2964. PDF</p>
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Initiation



Component 2

Lavigne, K.M., Metzak, P.D., & Woodward, T.S. (2015). Functional brain networks underlying detection and integration of disconfirmatory evidence. *NeuroImage* 112(2015): 138-151. [PDF](#)

Component 1

Lavigne, K.M., Rapin, L.A., Metzak, P.D., Whitman, J.C., Jung, K., Dohen, M., Loevenbruck, H., & Woodward, T.S. (2015). Left-dominant temporal-frontal hypercoupling in schizophrenia patients with hallucinations during speech perception. *Schizophrenia Bulletin*, 41(1): 259-267. [PDF](#)

Component 2

Metzak, P.D., Riley, J., Wang, L., Whitman, J.C., Ngan, E.T.C. & Woodward, T.S. (2012). Decreased efficiency of task-positive and task-negative networks during working memory in schizophrenia. *Schizophrenia Bulletin*, 38(4), 803-813. [PDF](#)

Component 2- Chapter 4 Analysis 1 WM

Component 1- Chapter 4 Analysis 4 TGT

Component 5- Chapter 5

Sanford, N. A. (2019). *Functional brain networks underlying working memory performance in schizophrenia : a multi-experiment approach* (T). University of British Columbia. Retrieved from <https://open.library.ubc.ca/collections/ubctheses/24/items/1.0387449>

Component 2- Single-Experiment

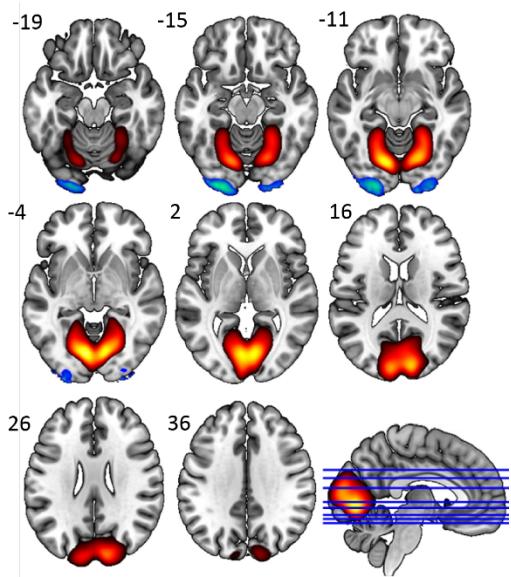
Component 2- Multi-Experiment

Sanford, N., Whitman, J.C. & Woodward, T.S. (2020). Task-Merging for finer separation of functional brain networks in working memory. *Cortex*, 125, 246-271.doi: 10.1016/j.cortex.2019.12.014. [PDF](#)

Component 1

Woodward, T.S., Feredoes, E., Metzak, P.D., Takane, Y., & Manoach, D.S. (2013). Epoch-specific functional networks involved in working memory. *NeuroImage*, 65: 529-539. [PDF](#)

Focus on Visual Features



Component 3

Lavigne, K.M., Metzak, P.D., & Woodward, T.S. (2015). Functional brain networks underlying detection and integration of disconfirmatory evidence. *NeuroImage* 112(2015): 138-151. [PDF](#)

Component 1- Chapter 4 Analysis 3 TSI

Component 7- Chapter 5

Sanford, N. A. (2019). *Functional brain networks underlying working memory performance in schizophrenia : a multi-experiment approach* (T). University of British Columbia. Retrieved from <https://open.library.ubc.ca/collections/ubctheses/24/items/1.0387449>

Component 6- Multi-Experiment

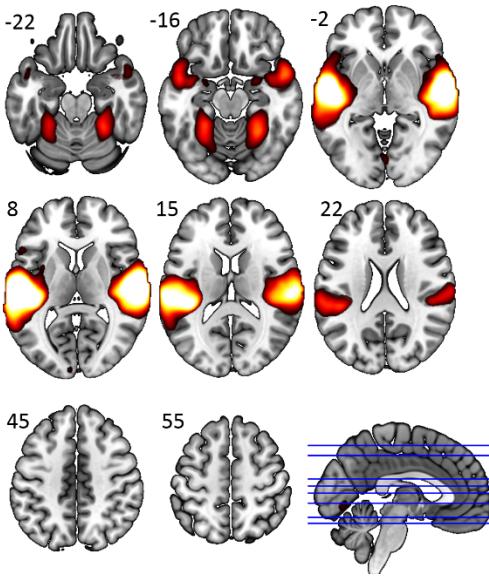
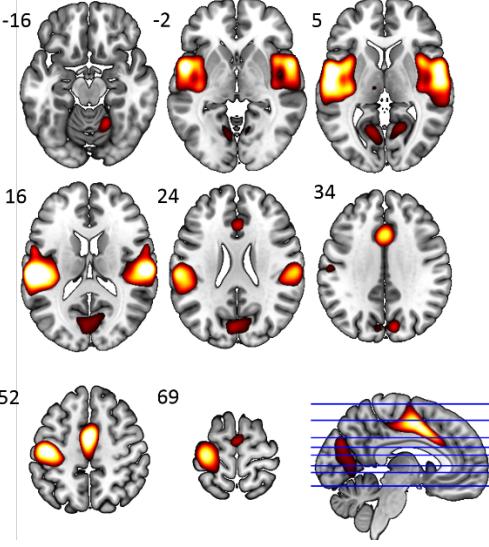
Sanford, N., Whitman, J.C. & Woodward, T.S. (2020). Task-Merging for finer separation of functional brain networks in working memory. *Cortex*, 125, 246-271.doi: 10.1016/j.cortex.2019.12.014. [PDF](#)

Component 4

Woodward, T.S., Feredoes, E., Metzak, P.D., Takane, Y., & Manoach, D.S. (2013). Epoch-specific functional networks involved in working memory. *NeuroImage*, 65: 529-539. [PDF](#)

Cognitive processes involved in attending to auditorily presented stimuli.

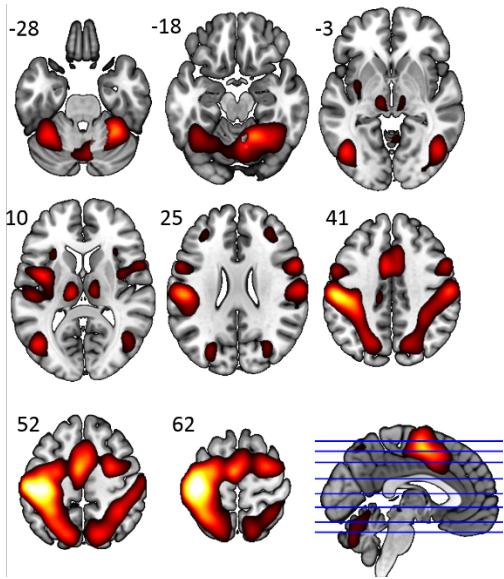
There are two networks which measure cognitive processes involved in attending to auditory stimuli in different ways. The first is *Auditory Perception* [3], active when listening to speech, and is hyperactive in hallucinations in schizophrenia [1]. The *Auditory Attention for Response* network is activated when auditory stimuli is being monitored when a response is required, but deactivated during intensive monitoring of visual details [1, 12], which is analogous to the familiar situation where someone is visually monitoring their phone, they are less likely to hear what you're saying to them.

Auditory Perception		<p>Component 4- Chapter 4 Analysis 4 TGT Sanford, N. A. (2019). <i>Functional brain networks underlying working memory performance in schizophrenia : a multi-experiment approach (T)</i>. University of British Columbia. Retrieved from https://open.library.ubc.ca/collections/ubctheses/24/items/1.0387449</p> <p>Component 7- Multi-Experiment Sanford, N., Whitman, J.C. & Woodward, T.S. (2020). Task-Merging for finer separation of functional brain networks in working memory. <i>Cortex</i>, 125, 246-271.doi: 10.1016/j.cortex.2019.12.014. PDF</p>
Auditory Attention for Response		<p>Component 2 Lavigne, K.M., Menon, M., & Woodward, T.S. (2016). Impairment in subcortical suppression in schizophrenia: Evidence from the fBIRN oddball task. <i>Human Brain Mapping</i>, 37:4640-4653. PDF</p> <p>Component 1 Lavigne, K.M. & Woodward, T.S. (2018). Hallucination and speech-specific hypercoupling in frontotemporal auditory and language networks in schizophrenia using combined task-based fMRI data: An fBIRN study. <i>Human Brain Mapping</i>, 2018(39):1582–1595. PDF</p> <p>Component 3- Chapter 5 Sanford, N. A. (2019). <i>Functional brain networks underlying working memory performance in schizophrenia : a multi-experiment approach (T)</i>. University of British Columbia. Retrieved from https://open.library.ubc.ca/collections/ubctheses/24/items/1.0387449</p>

Sensorimotor Processes.

Motor Response network is involved in responding, with a HDR that peaks late in the trial, but it is lateralized for one-handed response [3], and bilateral for a two-handed response [2, 4].

One-Handed Response



Component 1

Larivière, S., Lavigne, K.M., Woodward, T.S., Gerretsen, P., Graff-Guerrero, A., & Menon, M. (2017). Altered functional connectivity in brain networks underlying self-referential processing in delusions of reference in schizophrenia. *Psychiatry Research: Neuroimaging*, 263 (2017): 32–43. [PDF](#)

Component 3

Lavigne, K.M., Menon, M., Moritz, S. & Woodward, T.S. (2020). Functional brain networks underlying evidence integration and delusional ideation. *Schizophrenia Research*, doi:10.1016/j.schres.2019.11.038. [PDF](#)

Component 4

Lavigne, K.M., Metzak, P.D., & Woodward, T.S. (2015). Functional brain networks underlying detection and integration of disconfirmatory evidence. *NeuroImage* 112(2015): 138-151. [PDF](#)

Component 1- Chapter 4 Analysis 1 WM

Component 4- Chapter 5

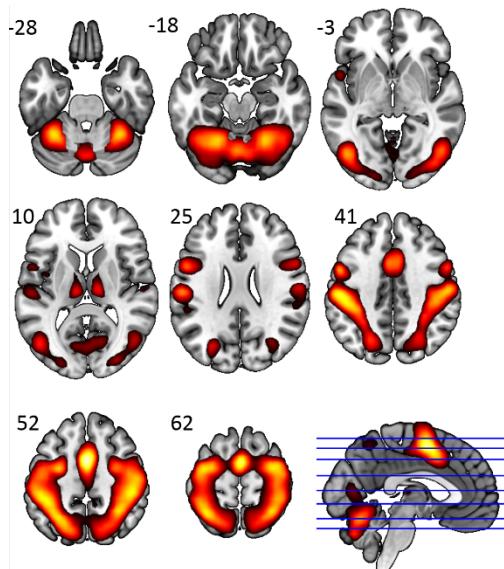
Sanford, N. A. (2019). *Functional brain networks underlying working memory performance in schizophrenia : a multi-experiment approach* (T). University of British Columbia. Retrieved from <https://open.library.ubc.ca/collections/ubctheses/24/items/1.0387449>

Component 1- Single-Experiment

Component 1- Multi-Experiment

Sanford, N., Whitman, J.C. & Woodward, T.S. (2020). Task-Merging for finer separation of functional brain networks in working memory. *Cortex*, 125, 246-271.doi: 10.1016/j.cortex.2019.12.014. [PDF](#)

Two-Handed Response



Component 1

Goghari, V.M., Sanford, N., Spilka, M.J. & Woodward, T.S. (2017). Task-related functional connectivity analysis of emotion discrimination in a family study of schizophrenia. *Schizophrenia Bulletin*, 43(6):1348–1362. [PDF](#)

Component 1

Metzak, P.D., Lavigne, K.M., & Woodward, T.S. (2015). Functional brain networks involved in reality monitoring. *Neuropsychologia* 75(2015) : 50-60. [PDF](#)

Component 1- Chapter 4 Analysis 2 SCAP

Component 2- Chapter 4 Analysis 3 TSI

Sanford, N. A. (2019). *Functional brain networks underlying working memory performance in schizophrenia : a multi-experiment approach* (T). University of British Columbia. Retrieved from <https://open.library.ubc.ca/collections/ubctheses/24/items/1.0387449>

Component 1

Whitman, J.C., Metzak, P.D., Lavigne, K.M., & Woodward, T.S. (2013). Functional connectivity in a frontoparietal network involving the dorsal anterior cingulate cortex underlies decisions to accept a hypothesis. *Neuropsychologia*, 51(2013):1132–1141. [PDF](#)

Component 2

Wong, S.T.S., Goghari, V.M., Sanford, N., Lim, R., Clark, C., Metzak, P.D., Rossell, S.L., Menon, M. & Woodward, T.S. (2020). Functional brain networks involved in lexical decision. *Brain and Cognition*, 138, doi: 10.1016/j.bandc.2019.103631. [PDF](#)

Component 2

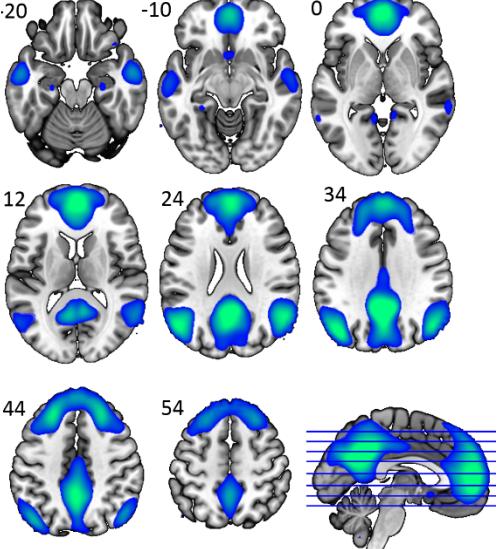
Woodward, T.S., Feredoes, E., Metzak, P.D., Takane, Y., & Manoach, D.S. (2013). Epoch-specific functional networks involved in working memory. *NeuroImage*, 65: 529-539. [PDF](#)

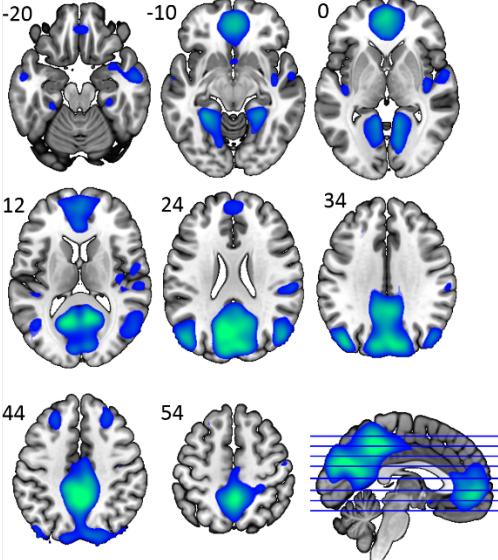
Component 1

Woodward, T.S., Leong, K., Sanford, N., Tipper, C.M., & Lavigne, K.M. (2016). Altered balance of functional brain networks in schizophrenia. *Psychiatry Research: Neuroimaging*, 248:94-104. [PDF](#)

Self-reflection/Imagining.

There are two networks thought to be involved in *Self Reflection/Imagining* [2, 4]. They both decrease activity when carrying out a task, unless that task is imagining a past or future event [6]. We call them default-mode network (DMN) A and B. DMN A is commonly found in resting state research, but DMN B appears to be detectable only in task-based fMRI.

Default Mode A		<u>Component 2</u> Goghari, V.M., Sanford, N., Spilka, M.J. & Woodward, T.S. (2017). Task-related functional connectivity analysis of emotion discrimination in a family study of schizophrenia. <i>Schizophrenia Bulletin</i> , 43(6):1348–1362. PDF
		<u>Component 2- Study 2</u> <u>Component 2- Study 3</u> Lavigne, K. M. (2018). <i>Cognitive biases and functional brain networks underlying delusions in schizophrenia</i> (T). University of British Columbia. Retrieved from https://open.library.ubc.ca/collections/ubctheses/24/items/1.0364055
		<u>Component 1</u> Lavigne, K.M., Menon, M., Moritz, S. & Woodward, T.S. (2020). Functional brain networks underlying evidence integration and delusional ideation. <i>Schizophrenia Research</i> , doi:10.1016/j.schres.2019.11.038. PDF
		<u>Component 4</u> Lavigne, K.M., Metzak, P.D., & Woodward, T.S. (2015). Functional brain networks underlying detection and integration of disconfirmatory evidence. <i>NeuroImage</i> 112(2015): 138-151. PDF
		<u>Component 3- Chapter 4 Analysis 1 WM</u> <u>Component 2- Chapter 4 Analysis 2 SCAP</u> <u>Component 1- Chapter 5</u> Sanford, N. A. (2019). <i>Functional brain networks underlying working memory performance in schizophrenia : a multi-experiment approach</i> (T). University of British Columbia. Retrieved from https://open.library.ubc.ca/collections/ubctheses/24/items/1.0387449
		<u>Component 3- Single-Experiment</u> <u>Component 4- Multi-Experiment</u> Sanford, N., Whitman, J.C. & Woodward, T.S. (2020). Task-Merging for finer separation of functional brain networks in working memory. <i>Cortex</i> , 125, 246-271.doi: 10.1016/j.cortex.2019.12.014. PDF

	<p><u>Component 2</u> Whitman, J.C., Metzak, P.D., Lavigne, K.M., & Woodward, T.S. (2013). Functional connectivity in a frontoparietal network involving the dorsal anterior cingulate cortex underlies decisions to accept a hypothesis. <i>Neuropsychologia</i>, 51(2013):1132–1141. PDF</p> <p><u>Component 1</u> Wong, S.T.S., Goghari, V.M., Sanford, N., Lim, R., Clark, C., Metzak, P.D., Rossell, S.L., Menon, M. & Woodward, T.S. (2020). Functional brain networks involved in lexical decision. <i>Brain and Cognition</i>, 138, doi: 10.1016/j.bandc.2019.103631. PDF</p> <p><u>Component 2</u> Woodward, T.S., Leong, K., Sanford, N., Tipper, C.M., & Lavigne, K.M. (2016). Altered balance of functional brain networks in schizophrenia. <i>Psychiatry Research: Neuroimaging</i>, 248:94-104. PDF</p> <p><u>Component 2</u> Woodward, T.S., Tipper, C.M., Leung, A., Lavigne, K.M., Sanford, N., Metzak, P.D. (2015). Reduced functional connectivity during controlled semantic integration in schizophrenia: A multivariate approach. <i>Human Brain Mapping</i>, 36: 2948-2964. PDF</p>
Default Mode B	 <p><u>Component 3</u> Metzak, P.D., Riley, J., Wang, L., Whitman, J.C., Ngan, E.T.C. & Woodward, T.S. (2012). Decreased efficiency of task-positive and task-negative networks during working memory in schizophrenia. <i>Schizophrenia Bulletin</i>, 38(4), 803-813. PDF</p> <p><u>Component 3</u> Wong, S.T.S., Goghari, V.M., Sanford, N., Lim, R., Clark, C., Metzak, P.D., Rossell, S.L., Menon, M. & Woodward, T.S. (2020). Functional brain networks involved in lexical decision. <i>Brain and Cognition</i>, 138, doi: 10.1016/j.bandc.2019.103631. PDF</p>

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7. Lavigne, K., Menon, M., Moritz, S., and Woodward, T.S., *Functional brain networks underlying evidence integration and delusional ideation*. Schizophrenia Research, 2020. 216: p. 302-309.
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12. Lavigne, K., Menon, M., and Woodward, T.S., *Impairment in subcortical suppression in schizophrenia: Evidence from the fBIRN oddball task*. Human Brain Mapping, 2016. 37: p. 4640-4653.