

Composing HL7 FHIR Resource Server



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Ph.D. Candidate

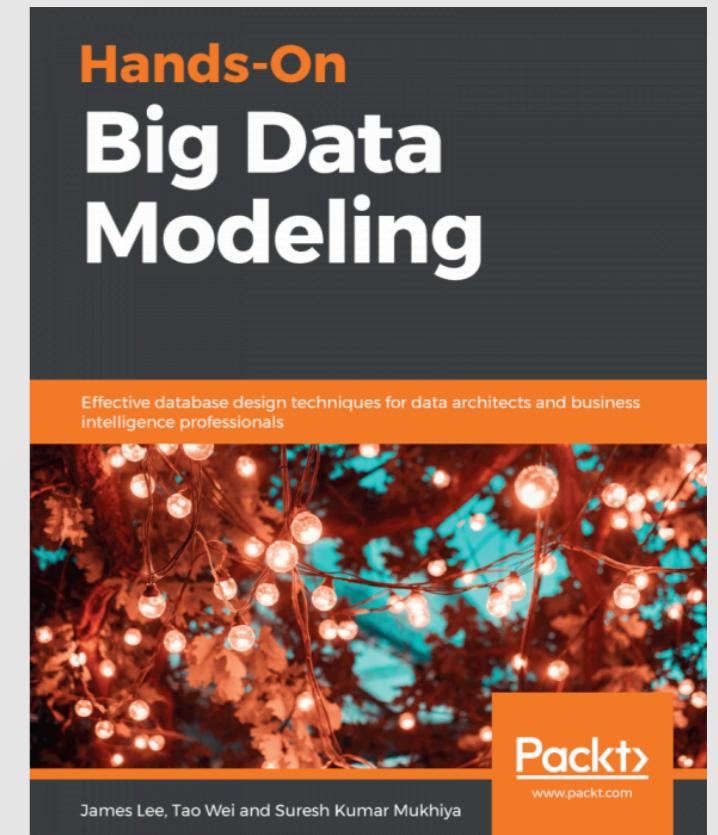
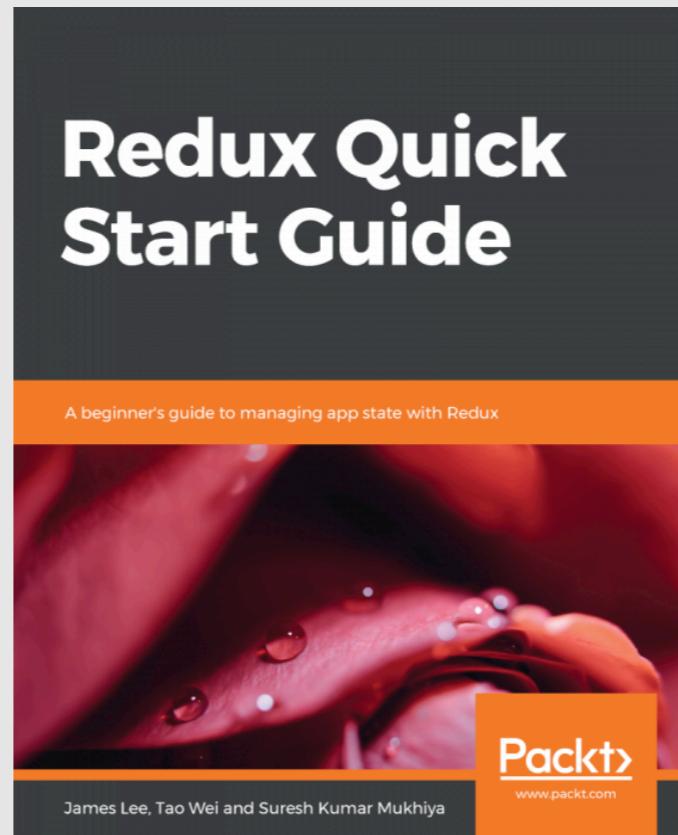
INTROMAT

Who AM I?

- Masters in Information System from NTNU, Trondheim,
- Have been working as Frontend Developer for 8 years, mostly remote work, for Silicon Valley Project
- Two technical books:



www.skmukhiya.com.np



Agenda



Introduction

Brief Intro to HL7 FHIR



Why

Why should we use?



Architecture

Main components



How?

Request/Response



Prototype

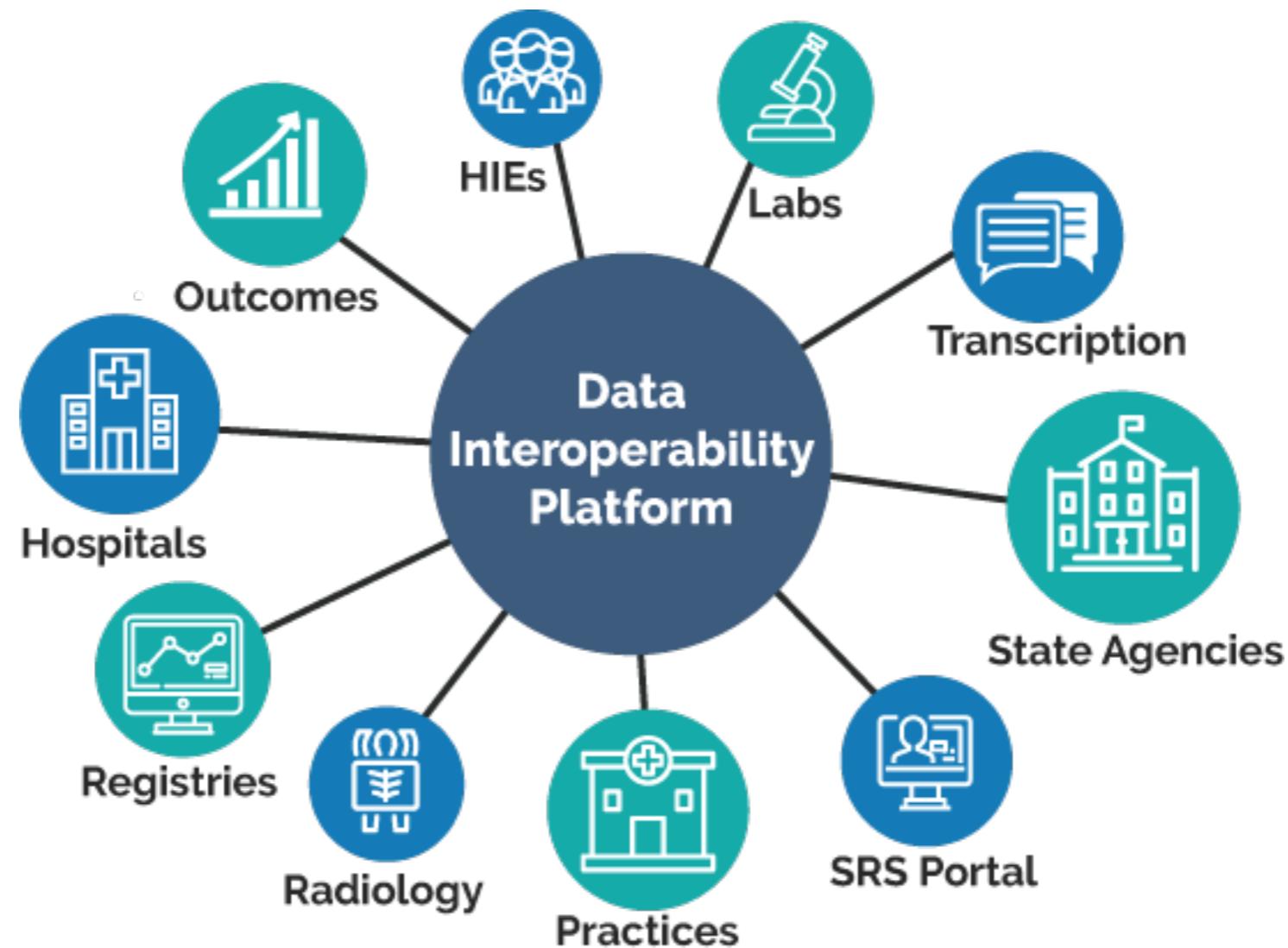
Based on HL7 FHIR



Discussion

Conclusion and Summary

Why HL7 FHIR?



HL7 FHIR

HL7 FHIR

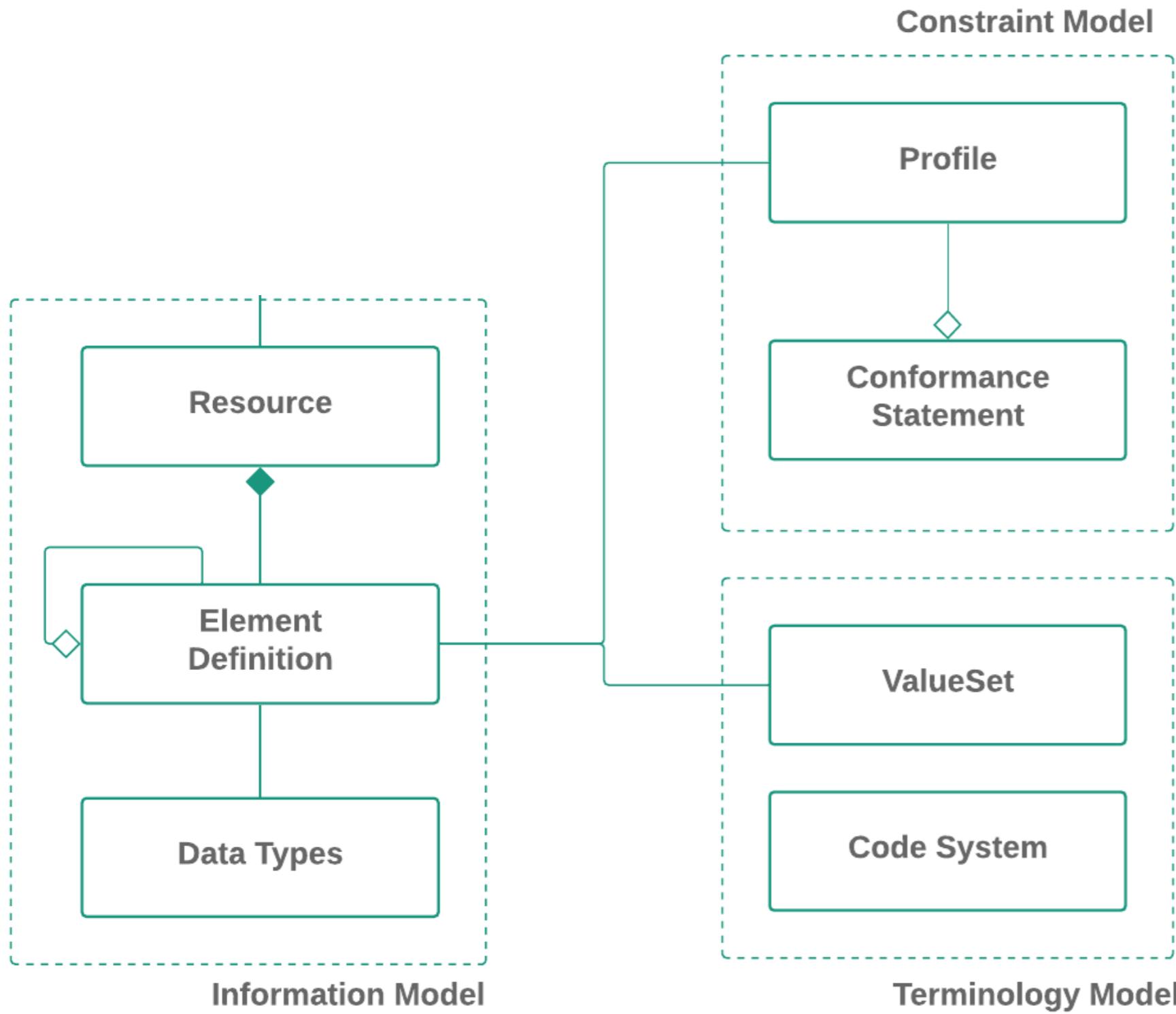
- designed to enable information exchange to support the provision of healthcare in a wide variety of settings.
 - FHIR is based on "Resources" which are the common building blocks for all exchanges.
-
- FHIR cover 80 percent of data elements used in existing healthcare systems currently.
 - The remaining 20 percent are specific use cases that can be dealt with as FHIR extensions.



HL7 FHIR Resources

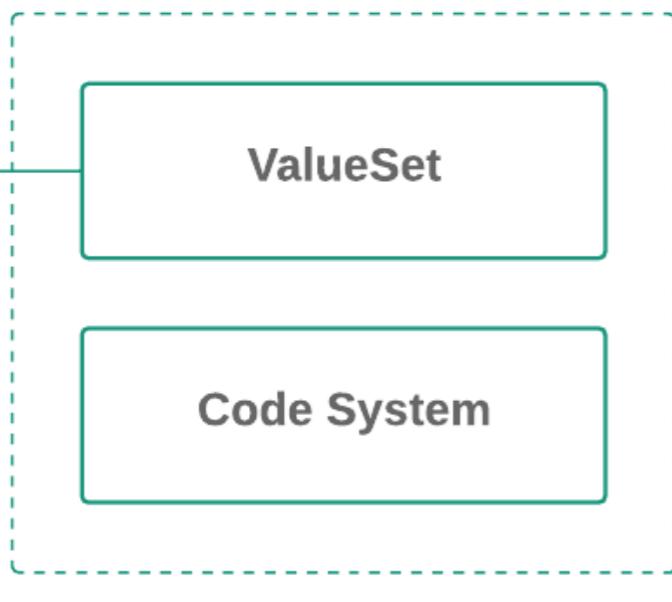
	Conformance	Terminology	Security	Documents	Other
Foundation	<ul style="list-style-type: none"> CapabilityStatement N StructureDefinition N ImplementationGuide 1 SearchParameter 3 MessageDefinition 1 OperationDefinition N CompartmentDefinition 1 StructureMap 2 GraphDefinition 1 ExampleScenario 0 	<ul style="list-style-type: none"> CodeSystem N ValueSet N ConceptMap 3 NamingSystem 1 TerminologyCapabilities 0 	<ul style="list-style-type: none"> Provenance 3 AuditEvent 3 Consent 2 	<ul style="list-style-type: none"> Composition 2 DocumentManifest 2 DocumentReference 3 CatalogEntry 0 	<ul style="list-style-type: none"> Basic 1 Binary N Bundle N Linkage 0 MessageHeader 4 OperationOutcome N Parameters N Subscription 3
Base	Individuals <ul style="list-style-type: none"> Patient N Practitioner 3 PractitionerRole 2 RelatedPerson 2 Person 2 Group 1 	Entities #1 <ul style="list-style-type: none"> Organization 3 OrganizationAffiliation 0 HealthcareService 2 Endpoint 2 Location 3 	Entities #2 <ul style="list-style-type: none"> Substance 2 BiologicallyDerivedProduct 0 Device 0 DeviceMetric 1 	Workflow <ul style="list-style-type: none"> Task 2 Appointment 3 AppointmentResponse 3 Schedule 3 Slot 3 VerificationResult 0 	Management <ul style="list-style-type: none"> Encounter 2 EpisodeOfCare 2 Flag 1 List 1 Library 2
Clinical	Summary <ul style="list-style-type: none"> AllergyIntolerance 3 AdverseEvent 0 Condition (Problem) 3 Procedure 3 FamilyMemberHistory 2 ClinicalImpression 0 DetectedIssue 1 	Diagnostics <ul style="list-style-type: none"> Observation N Media 1 DiagnosticReport 3 Specimen 2 BodyStructure 1 ImagingStudy 3 QuestionnaireResponse 3 MolecularSequence 1 	Medications <ul style="list-style-type: none"> MedicationRequest 3 MedicationAdministration 2 MedicationDispense 2 MedicationStatement 3 Medication 3 MedicationKnowledge 0 Immunization 3 ImmunizationEvaluation 0 ImmunizationRecommendation 1 	Care Provision <ul style="list-style-type: none"> CarePlan 2 CareTeam 2 Goal 2 ServiceRequest 2 NutritionOrder 2 VisionPrescription 2 RiskAssessment 1 RequestGroup 2 	Request & Response <ul style="list-style-type: none"> Communication 2 CommunicationRequest 2 DeviceRequest 0 DeviceUseStatement 0 GuidanceResponse 2 SupplyRequest 1 SupplyDelivery 1
Financial	Support <ul style="list-style-type: none"> Coverage 2 CoverageEligibilityRequest 2 CoverageEligibilityResponse 2 	Billing <ul style="list-style-type: none"> Claim 2 ClaimResponse 2 Invoice 0 	Payment <ul style="list-style-type: none"> PaymentNotice 2 PaymentReconciliation 2 	General <ul style="list-style-type: none"> Account 2 ChargeItem 0 ChargeItemDefinition 0 	

HL7 FHIR Components



```
{  
  resourceType: "Patient",  
  name: [  
    {  
      family: "Solo",  
      given: [  
        "Leia"  
      ]  
    },  
    {  
      family: "Organa",  
      given: [  
        "Leia"  
      ]  
    }  
,  
    gender: "female",  
    birthDate: "1995-10-12"  
}
```

HL7 FHIR Components



Terminology Model

PATIENT HEALTH QUESTIONNAIRE (PHQ-9)

NAME: _____ DATE: _____

Over the last 2 weeks, how often have you been
bothered by any of the following problems?

(use "✓" to indicate your answer)

1. Little interest or pleasure in doing things
2. Feeling down, depressed, or hopeless
3. Trouble falling or staying asleep, or sleeping too much
4. Feeling tired or having little energy
5. Poor appetite or overeating
6. Feeling bad about yourself—or that you are a failure or have let yourself or your family down
7. Trouble concentrating on things, such as reading the newspaper or watching television
8. Moving or speaking so slowly that other people could have noticed. Or the opposite—being so fidgety or

Not at all	Several days	More than half the days	Nearly every day
0	1	2	3
0	1	2	3
0	1	2	3
0	1	2	3
0	1	2	3
0	1	2	3
0	1	2	3

HL7 FHIR Components

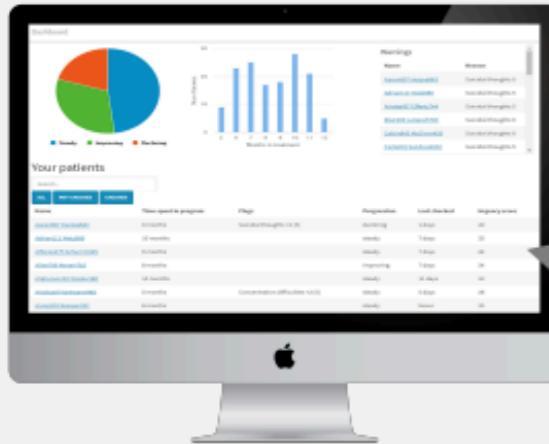
PATIENT HEALTH QUESTIONNAIRE (PHQ-9)

NAME: _____ DATE: _____

Over the last 2 weeks, how often have you been
bothered by any of the following problems?
(use "✓" to indicate your answer)

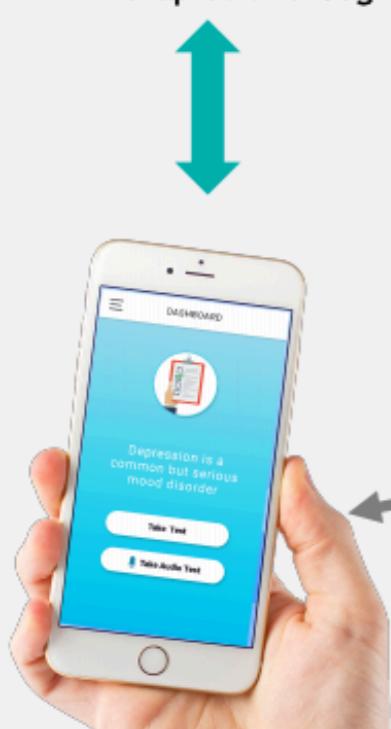
	Not at all	Several days	More than half the days	Nearly every day
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself—or that you are a failure or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed. Or the opposite—being so fidgety or				

```
{
  "linkId": "LittleInterest",
  "code": [
    {
      "system": "http://loinc.org",
      "code": "44250-9"
    }
  ],
  "text": "Little interest or pleasure in
          doing things",
  "type": "choice",
  "required": true,
  "answerValueSet": "http://loinc.org/vs/LL358
                    -3"
}
```



Web Client

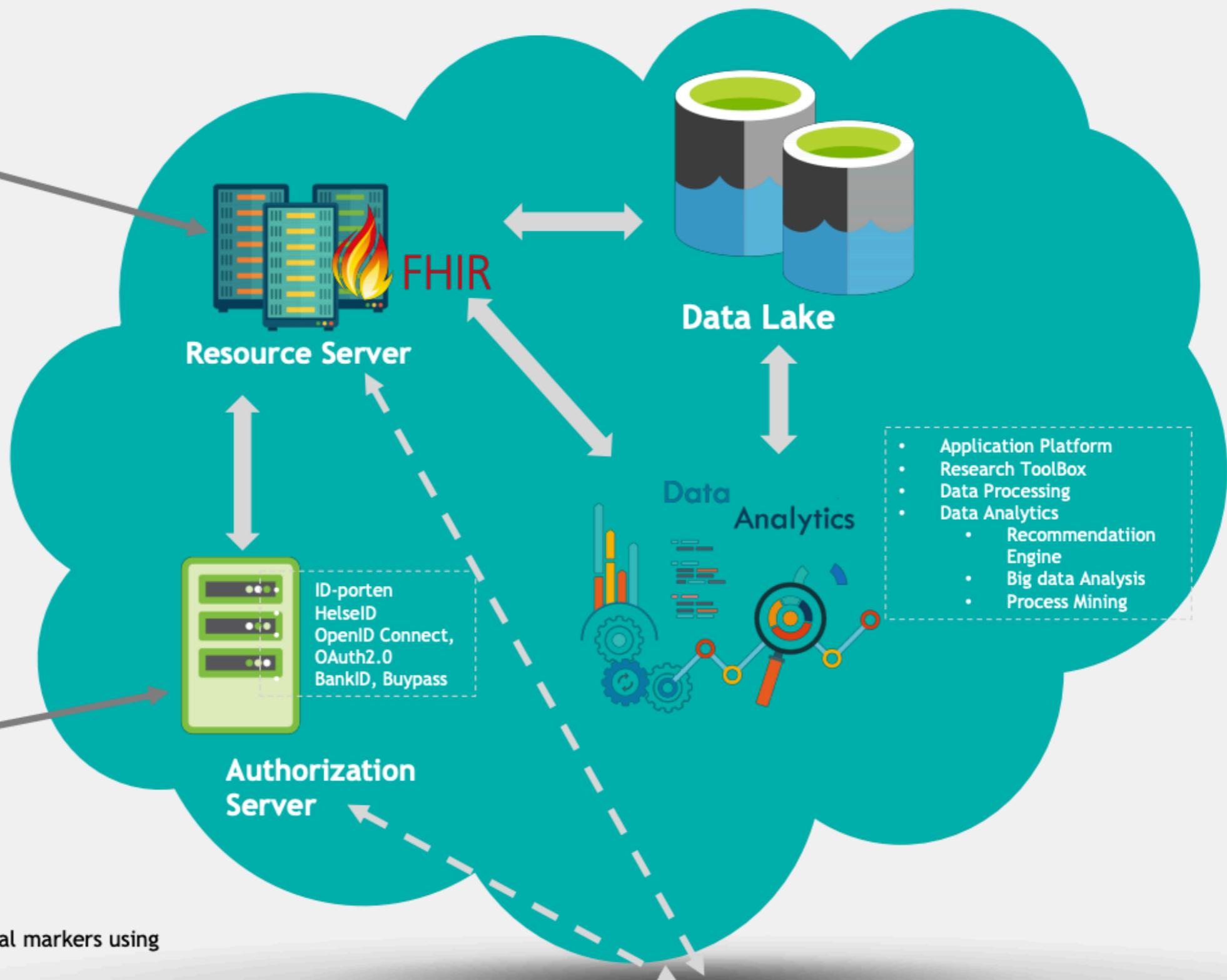
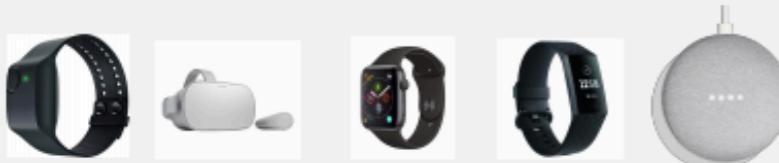
- Therapists' dashboard to visualize patient's information and monitor their progress
- Interface to create Internet Delivered Therapies like Cognitive Based Therapy.



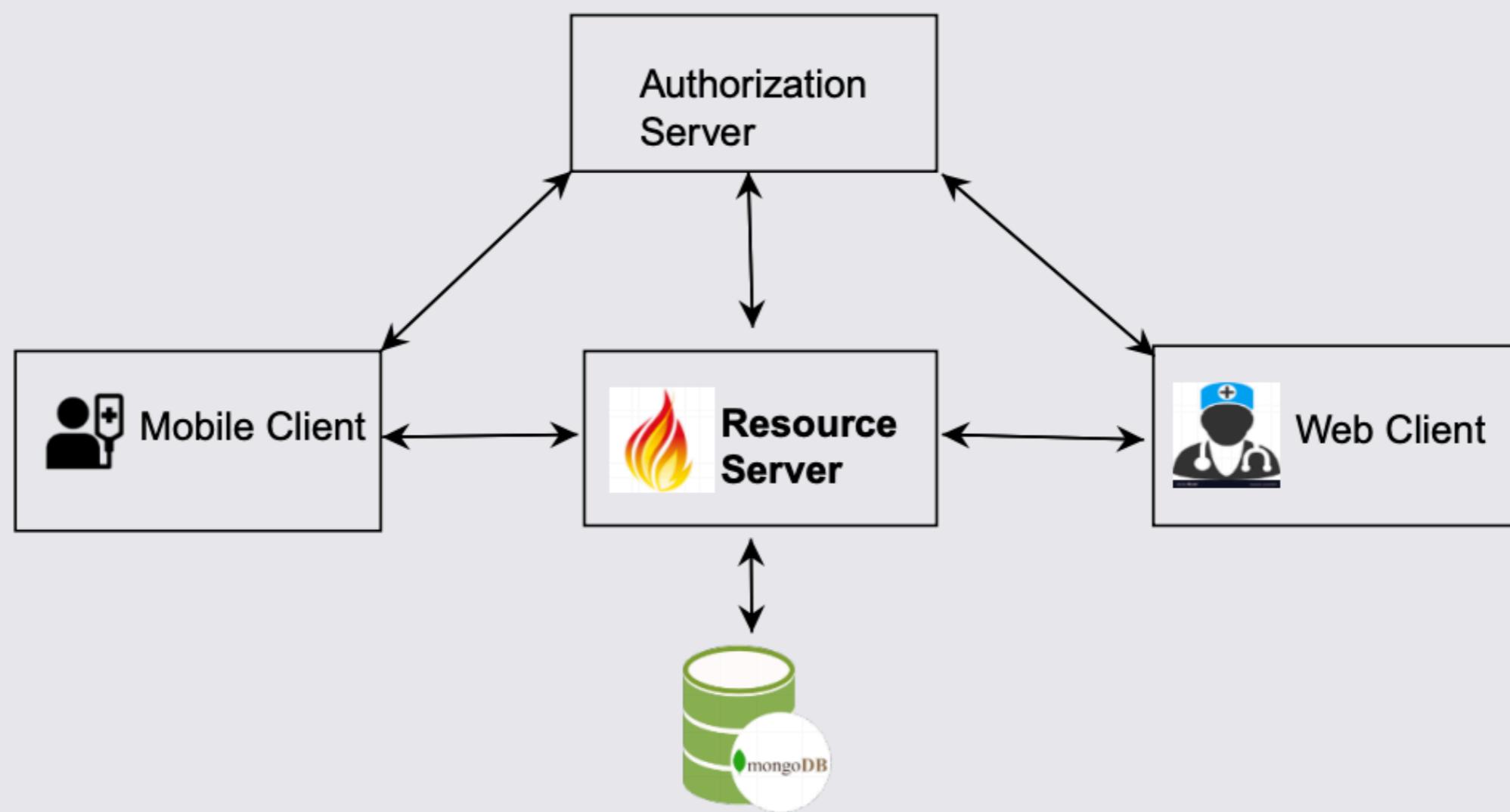
Mobile Client



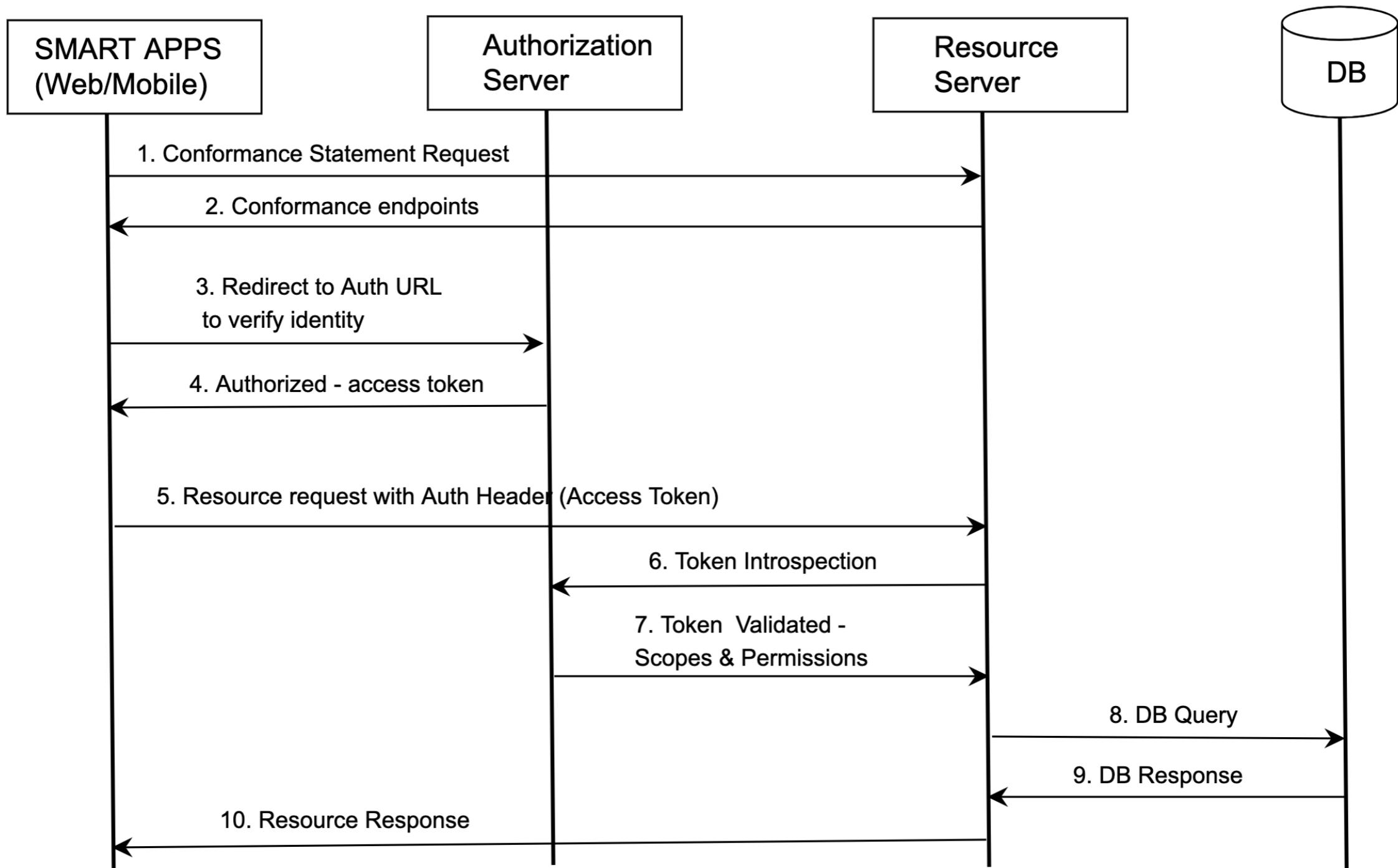
- Collects biological markers using sensors
- Provides CBT interface
- Conversational Agents interface
- Sensor devices connects to mobile-client using standard Bluetooth protocol.



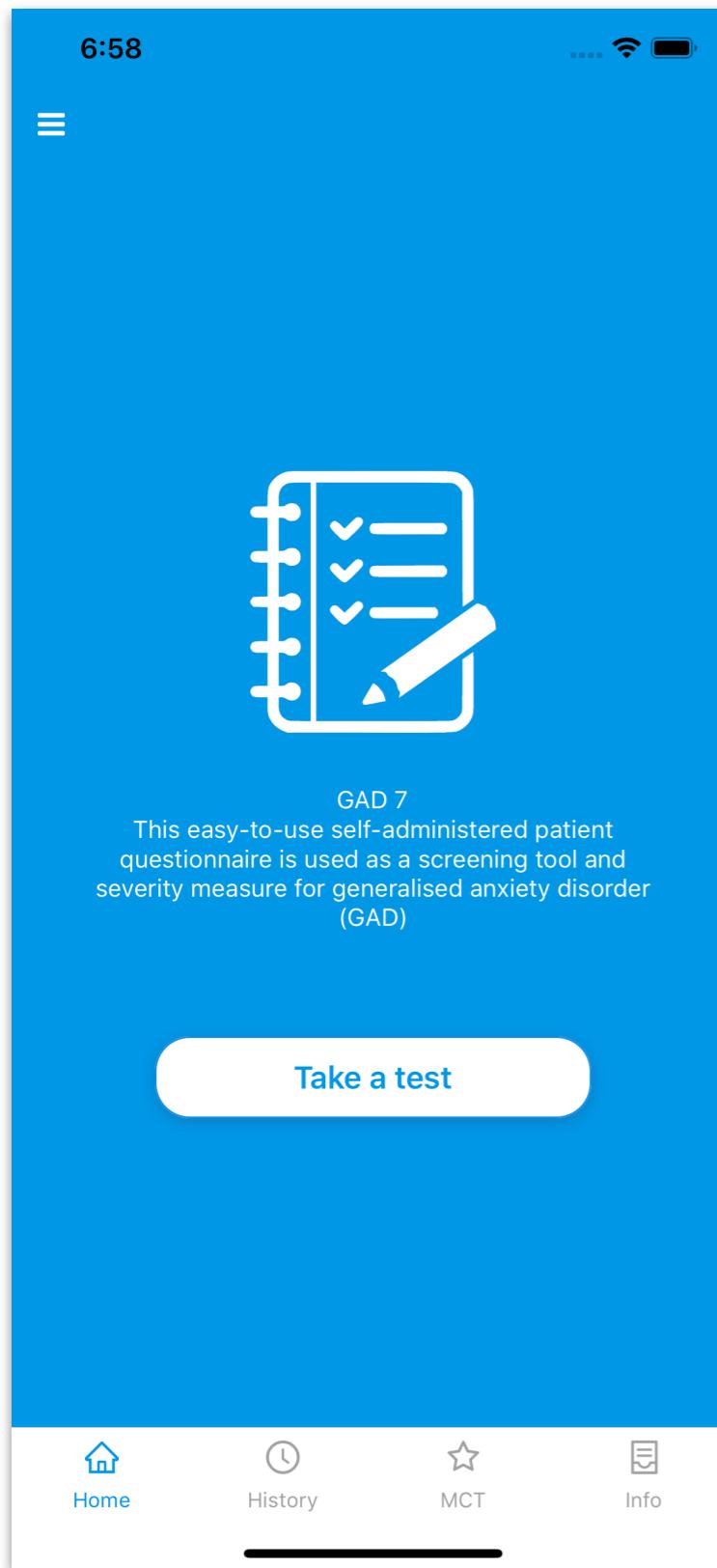
Simplified version



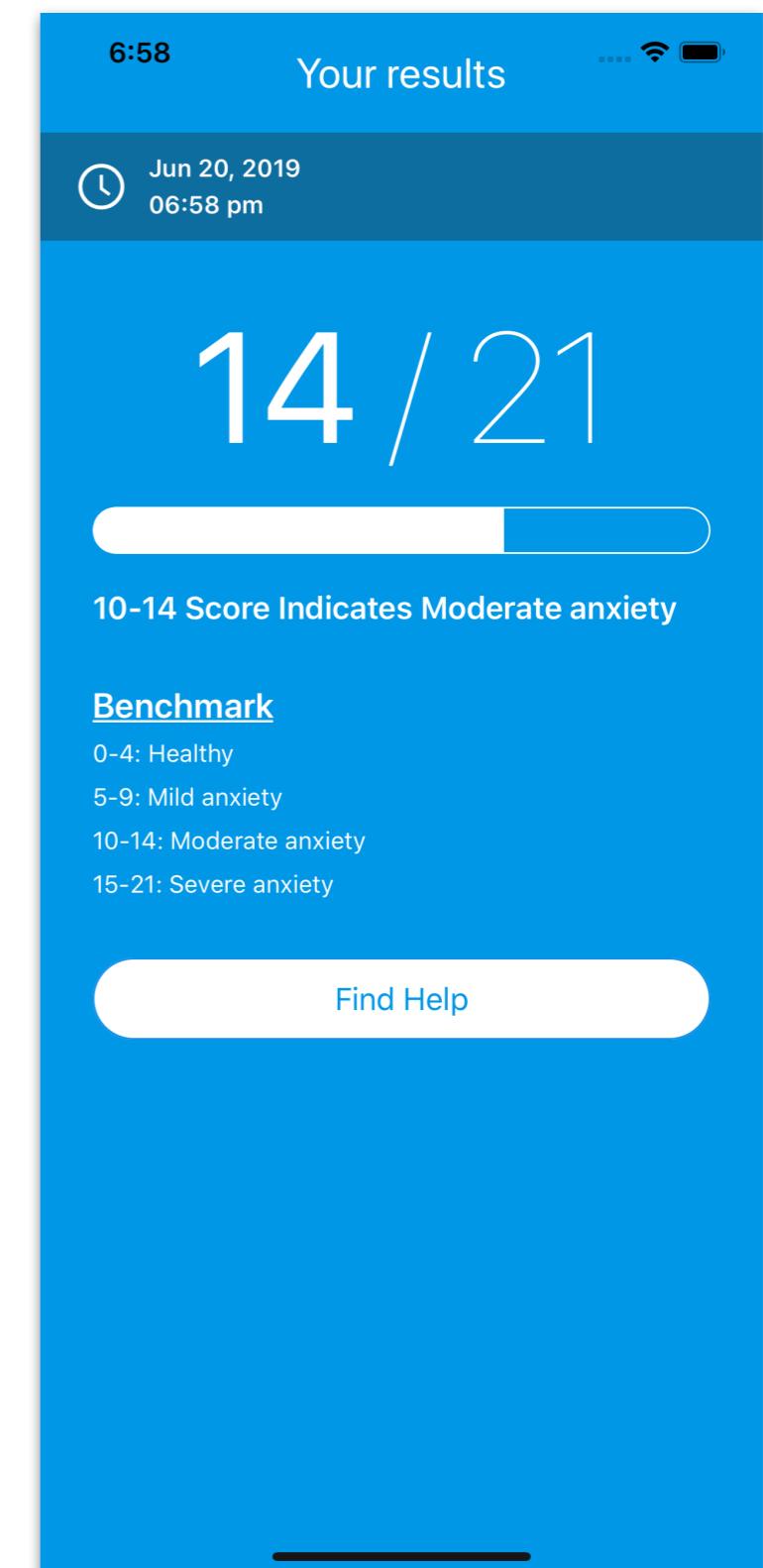
Communication Sequence



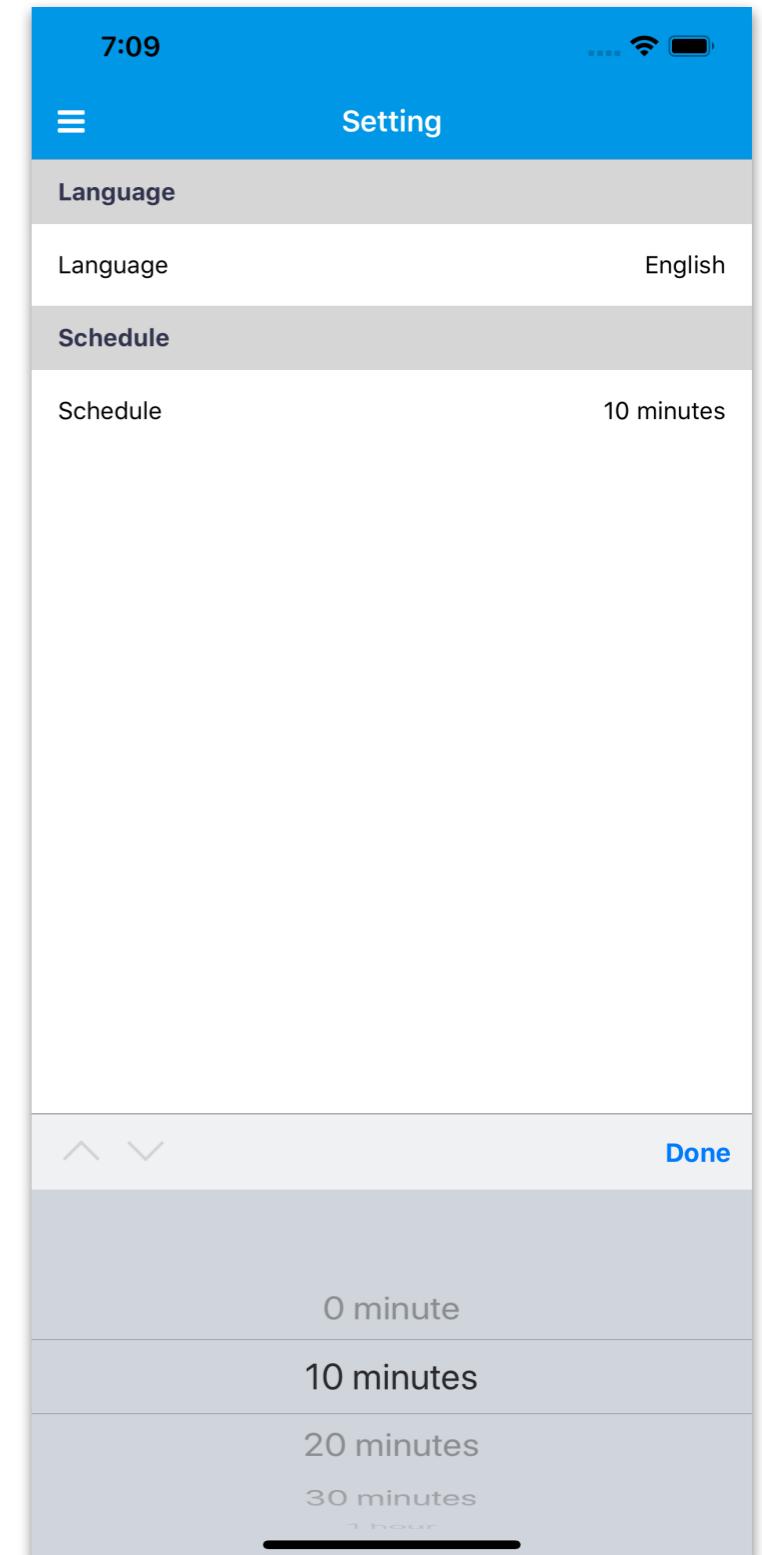
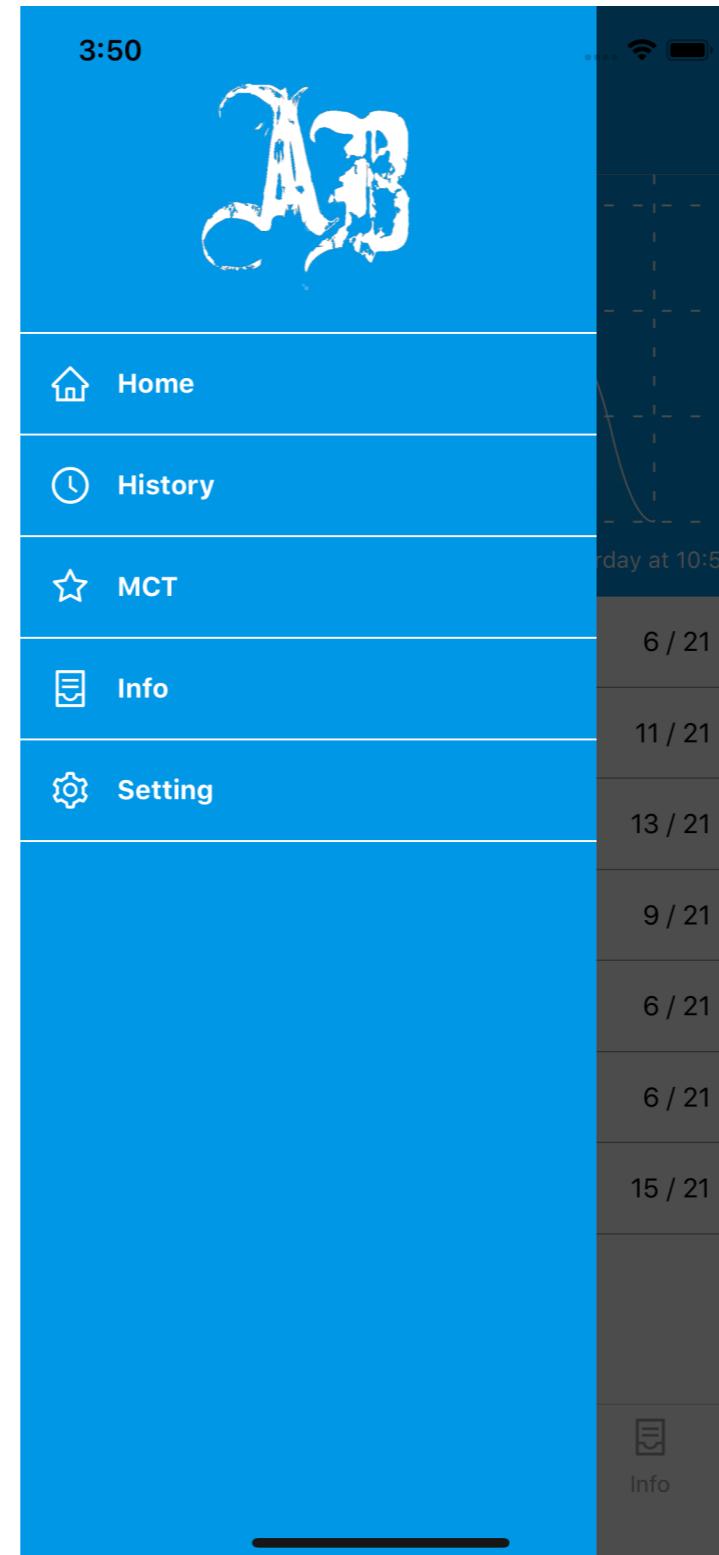
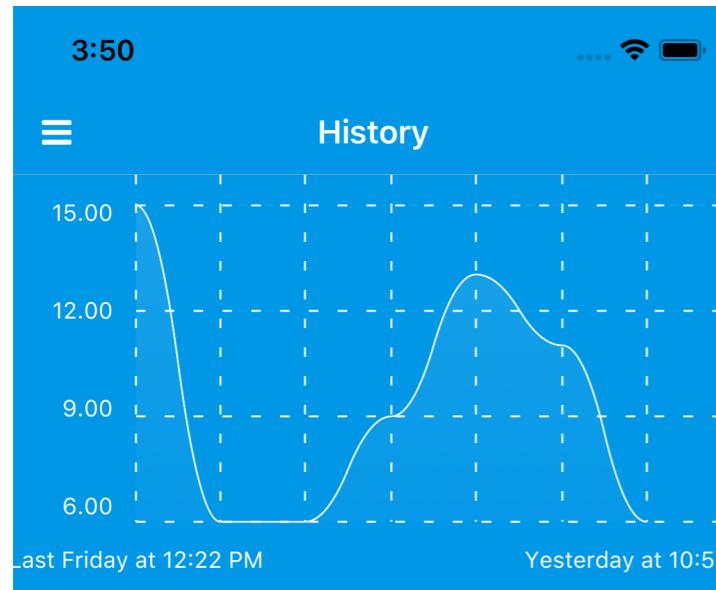
Mobile Client



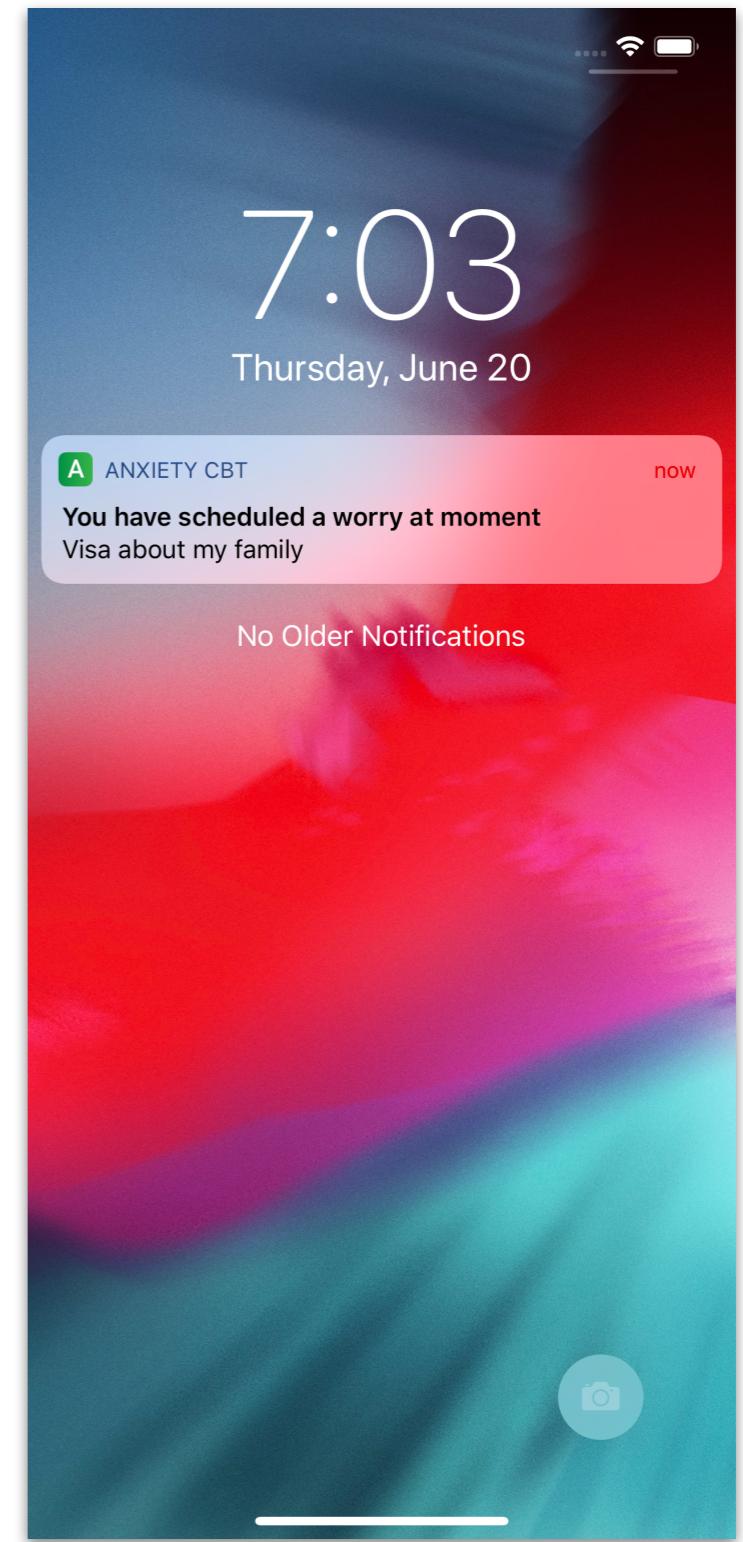
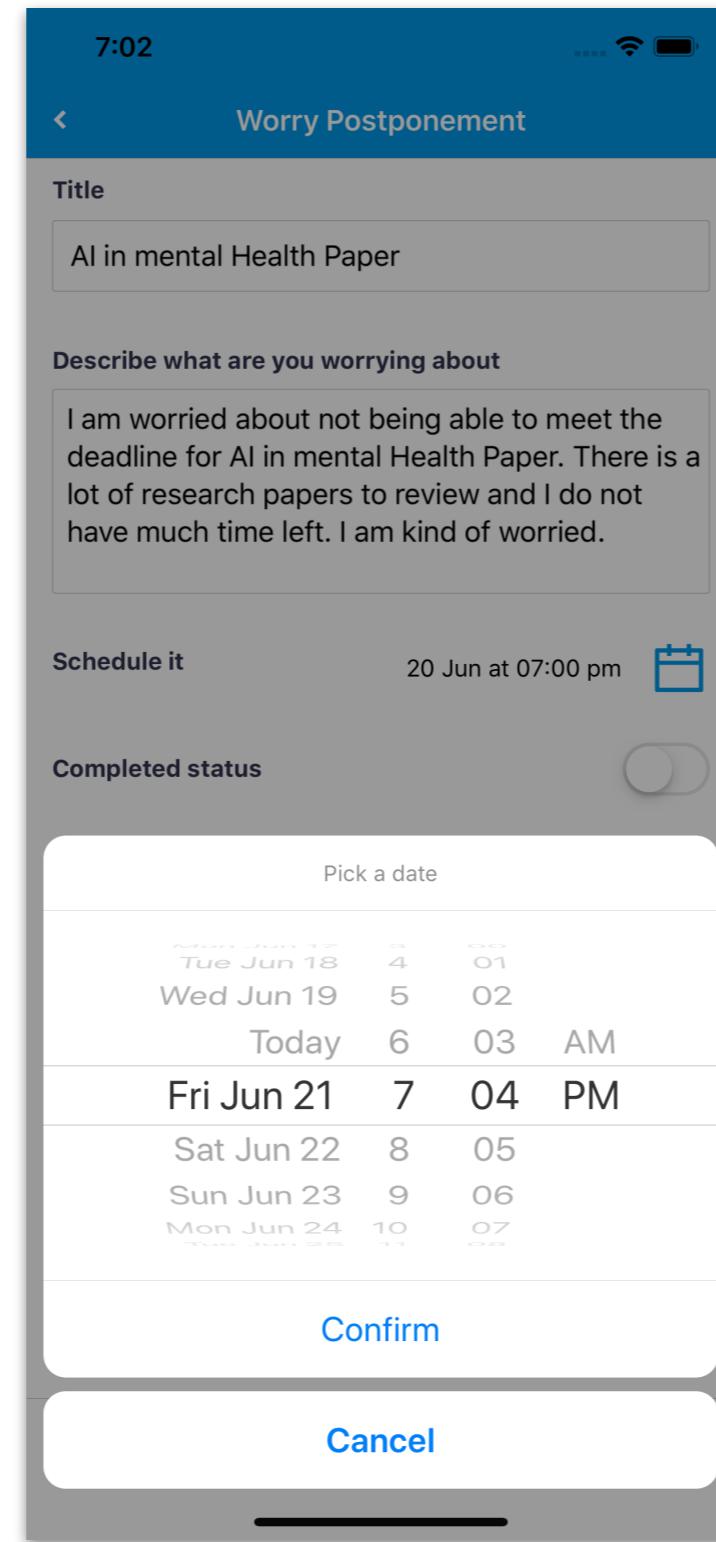
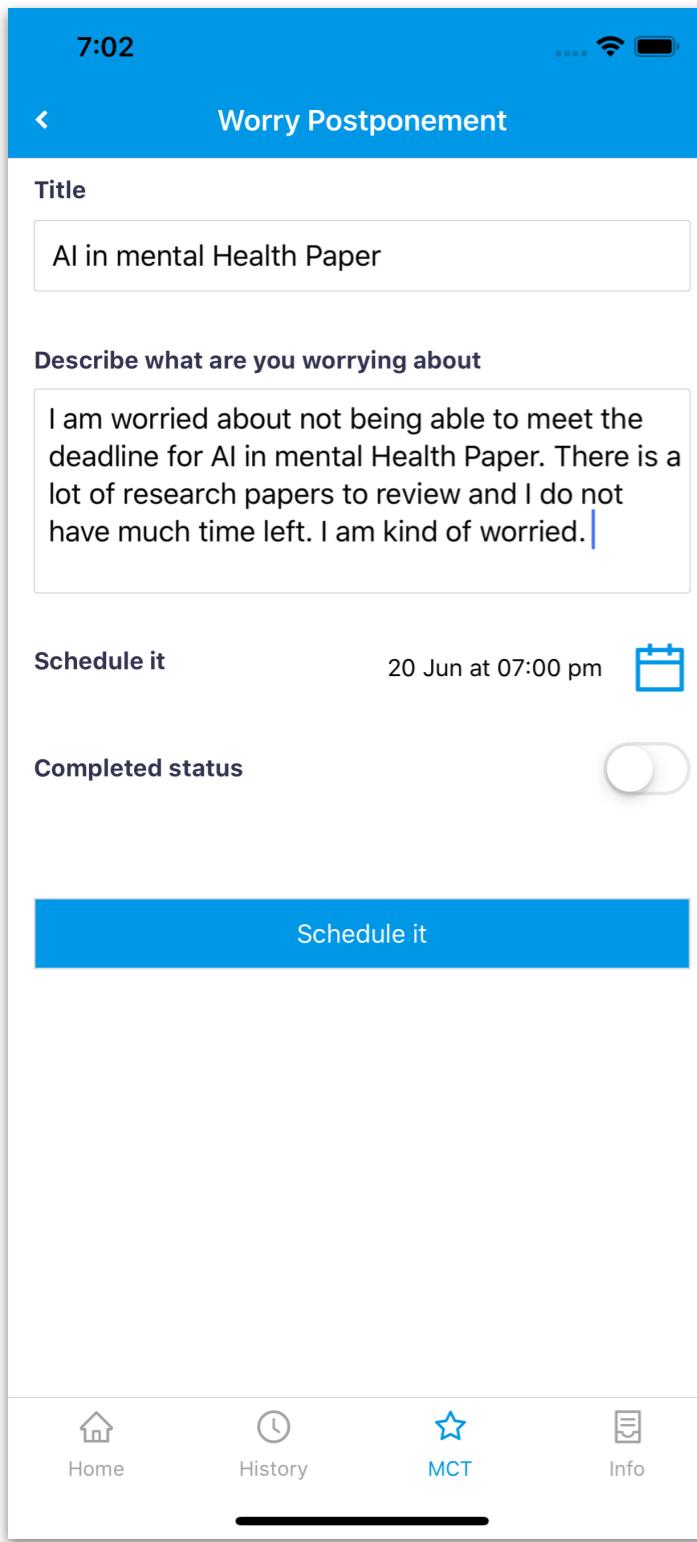
This screen shows the 7th question of the 7-question GAD scale. The question text is: "Feeling afraid as if something awful might happen". Below the question are four response options: "Not at all sure", "Several days", "Over half the days", and "Nearly everyday". The "Nearly everyday" option is highlighted with a blue background. At the bottom are two buttons: "Submit" and "Swipe to Next Question".



Mobile Client



Meta Cognitive Therapy



Next Step

Worry Text Understanding and Processing

I am worried that I will not be able to finish my research paper on time. The deadline is next week and I have a lot of research papers to review and write into the related section. I will have to review those papers and include them in my paper. This is very time-consuming.

```
{  
  "sentiment": {  
    "document": {  
      "score": -0.919775,  
      "label": "negative"  
    }  
  }  
  
{  
  "emotion": {  
    "document": {  
      "emotion": {  
        "sadness": 0.139152,  
        "joy": 0.072144,  
        "fear": 0.805766,  
        "disgust": 0.00955,  
        "anger": 0.107329  
      }  
    }  
  }  
}
```





Sign-in

Enter an email

and password

Stay signed in

Sign-in

[Cancel]

```
{ "error": "login_required",
  "error_description": "End-User
authentication could not be obtained",
  "reason": "login_prompt",
"reason_description": "nirmal_implicit
asks you to Sign-in again." }

{ "client_id": "nirmal_implicit",
"nonce": "foobar", "prompt": "login",
  "redirect_uri":
  "https://client.mhof.ml",
  "response_mode": "fragment",
  "response_type": "id_token token",
"scope": "openid email patient/*.*" }
```

Authorisation Server

Authorisation Server

- The authorisation server is an **OpenID** connect compliant web server with an ability to authenticate users and grant authorisation access tokens.
- Authorisation server manages **scopes** and **permission** of the clients, introspects token and requests for the resource server.

`http://oauth.mhof.ml/auth?
client_id=CLIENT_ID&response_
type=id_token+token&scope=ope
nid+email+patient/
.&nonce=foobar&prompt=login`

<code>response_type</code>	required
<code>client_id</code>	required
<code>redirect_uri</code>	required
<code>launch</code>	optional
<code>scope</code>	required
<code>state</code>	required

Customised Authorisation Server

LOGG IN MED BANKID <>

Available Resource Server



SPARK FHIR server

C# Reference Implementation for HL7 FHIR

Endpoint:
<http://spark.furore.com/fhir>



This is the homepage for the Pyro Server general purpose FHIR Server. The implementation is an open-source FHIR API built with C# and Microsoft's .NET 4.6 Framework and utilises the [official HL7 FHIR support API](#) for the Microsoft .NET platform. The implementation can use either a Microsoft SQL Server or a Postgre SQL database as its storage layer.

There are two version of the Pyro Server, STU3 and R4, which align with the [official releases](#) of the FHIR specification.

Publicly available Pyro FHIR servers

FHIR STU3 Endpoint
<https://stu3.test.pyrohealth.net/fhir>



Vonk FHIR Server

The FHIR reference server for .NET by the people who run SIMPLIFIER.NET

FHIR Endpoint <https://vonk.fire.ly/>



Products ▾

Services

Blog



OVERVIEW AIDBOX LINE

Platform
for FHIR-first
Healthcare Apps

<Hapi/> HAPI-FHIR
fhir made simple.

Resource Server



Hapi FHIR

- JAVA implementation
- REST API
- Supports all resource types, most operations, and both xml and JSON encodings

Resource Server

Not Secure | hapi.fhir.org

Home Server: UHN_HAPI Server (STU3 FHIR) Source Code About This Server

Options

Encoding (default) XML JSON

Pretty (default) On Off

Summary (none) true text data count

Server

Server Home/Actions

Resources

Patient	1139027
Observation	313660
MedicationAdministration	56327
MedicationStatement	42157
Encounter	31661
MedicationDispense	28413
Condition	22472
MedicationRequest	18638
Claim	16063
Procedure	11743
ValueSet	11526
Binary	10868
Practitioner	9807
ExplanationOfBenefit	9118
Immunization	8118
Medication	6817
Appointment	4910
DiagnosticReport	4040

<Hapi/> HAPI-FHIR fhir made simple.

You are accessing the public FHIR server **UHN_HAPI Server (STU3 FHIR)**. This server is hosted elsewhere on the internet but is being accessed using the HAPI client implementation.

⚠ This is not a production server! Do not store any information here that contains personal health information or any other confidential information. This server will be regularly purged and reloaded with fixed test data.

Server Actions

Retrieve the server's **conformance** statement.

Conformance

Retrieve the update **history** across all resource types on the server.

History Since Limit # (opt)

Post a bundle containing multiple resources to the server and store all resources within a single atomic transaction.

Transaction Bundle * (place transaction bundle body here)

Resource Server

- Base URL: <http://hapi.fhir.org/baseDstu3>

GET	/Patient	All Patients
POST	/Patient	Create Patient
GET	/Patient/649227	Single Patient
PUT	/Patient/649227	Update Patient
DELETE	/Patient/649227	Delete Patient

- <https://www.hl7.org/fhir/resourcelist.html> lists 143 HL7 FHIR resources.
- Assuming **Best Case**, each resource needs 5 endpoints (CRUD) resulting ($143 \times 5 = 715$) endpoints.
- **Worst Case:** Custom endpoints based on custom requirements. Eg. all patients over 30 years, all patients only from Bergen etc.

Revisiting Mobile Client

The figure consists of three side-by-side screenshots of a mobile application interface. All three screens show a blue header bar with signal strength, battery level (65%), and time (22:38 or 22:39). The first screen shows a large icon of a clipboard with a checklist and a pencil, followed by the text 'GAD 7' and a detailed description: 'This easy-to-use self-administered patient questionnaire is used as a screening tool and severity measure for generalised anxiety disorder (GAD)'. Below this is a white button labeled 'Take a test'. The second screen shows the title 'Generalized Anxiety Disorder 7 Item Scale (GAD-7)' and a detailed description of the scale's purpose and how often symptoms occurred over the last 2 weeks. It features a large 'Start' button and a 'Back' button. The third screen displays a single question: 'Feeling nervous, anxious, or on edge'. Below the question are four response options: 'Not At All Sure', 'Several Days', 'Over Half The Days', and 'Nearly Everyday'. A 'Swipe to Next Question' button is at the bottom. The bottom navigation bar for all three screens includes icons for Home, History, MCT, and Info.

MyCall 22:38 65 %

MyCall 22:38 65 %

MyCall 22:39 65 %

GAD 7
This easy-to-use self-administered patient questionnaire is used as a screening tool and severity measure for generalised anxiety disorder (GAD)

Take a test

Generalized Anxiety Disorder 7 Item Scale (GAD-7)
Generalized anxiety disorder (GAD) is one of the most common mental disorders; however, there is no brief clinical measure for assessing GAD. The objective of this study was to develop a brief self-report scale to identify probable cases of GAD and evaluate its reliability and validity. Over the last 2 weeks, how often have you been bothered by the following problems?

Start

Back

1 / 7

Feeling nervous, anxious, or on edge

Not At All Sure

Several Days

Over Half The Days

Nearly Everyday

Swipe to Next Question

Home History MCT Info

Home History MCT Info

Home History MCT Info

1. (name, description), 2. (name, description, title), 3. Question and options

Response From REST : Over-fetching

```
{  
  "resourceType": "Questionnaire",  
  "id": "anxiety-gad_7",  
  "text": {  
    "status": "generated",  
    "div": "<div xmlns='http://www.w3.org/1999/xhtml'>Generalized Anxiety disorder ? Item Scale (GAD-7)</div>"  
  },  
  "identifier": [  
    {  
      "use": "official",  
      "value": "anxiety-gad_7"  
    }  
  ],  
  "extension": [  
    {  
      "url": "http://hl7.org/fhir/StructureDefinition/questionnaire-calculated-value",  
      "valueBoolean": {  
        "description": "TODAY Full score evaluation here .8g: Score (0-4: healthy; 5-8: Moderate; 9-12: Serious)",  
        "language": "text/fhirpath",  
        "name": "score",  
        "expression": "QuestionnaireResponse.item.repetition.answer.valueCoding-extension.valueDecimal"  
      }  
    }  
  ],  
  "version": "1.0.0",  
  "title": "Generalized Anxiety Disorder 7 Item Scale (GAD-7)",  
  "code": [  
    {  
      "system": "http://pubs.bionontology.org/ontology/HBOPIDCT/16458188",  
      "code": "704581007",  
      "display": "Generalized anxiety disorder 7 item scale"  
    }  
  ],  
  "subjectType": [  
    "Patient"  
  ],  
  "contained": [  
    {  
      "resourceType": "ValueSet",  
      "id": "anxietygad",  
      "meta": {  
        "versionId": "1",  
        "lastUpdated": "2018-01-18T09:50:25.165+00:00"  
      },  
      "url": "http://mhof.ml/valueset/MHOFV5004",  
      "Identifier": [  
        {  
          "system": "urn:ietf:rfc3986",  
          "value": "urn:nid:1.3.6.1.4.1.12999.10.1.138"  
        }  
      ],  
      "version": "data.1",  
      "name": "GAD-7",  
      "title": "Generalized Anxiety Disorders 7 Item Scale (GAD-7)"  
    }  
  ]  
}
```

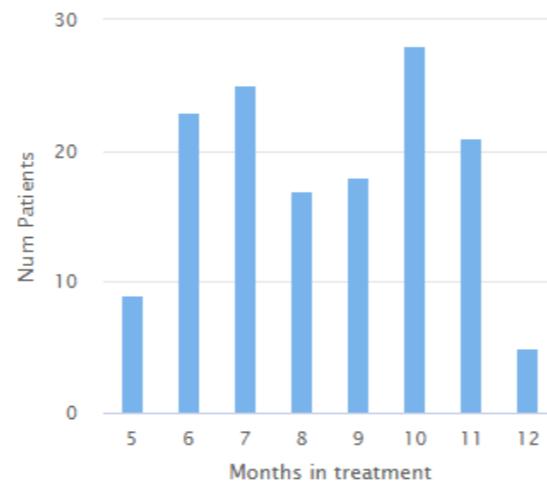
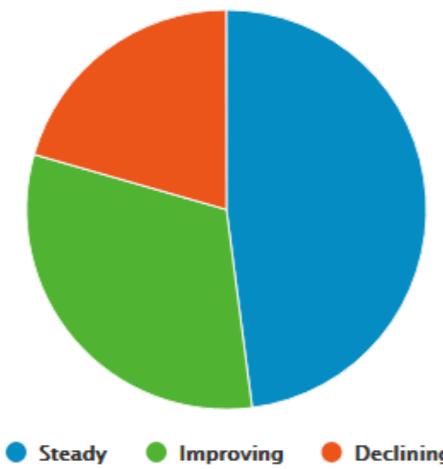
```
{  
  "resourceType": "Questionnaire",  
  "id": "anxiety-gad_7",  
  "text": {  
    "status": "generated",  
    "div": "<div xmlns='http://www.w3.org/1999/xhtml'>Generalized Anxiety disorder ? Item Scale (GAD-7)</div>"  
  },  
  "identifier": [  
    {  
      "use": "official",  
      "value": "anxiety-gad_7"  
    }  
  ],  
  "extension": [  
    {  
      "url": "http://hl7.org/fhir/StructureDefinition/questionnaire-calculated-value",  
      "valueBoolean": {  
        "description": "TODAY Full score evaluation here .8g: Score (0-4: healthy; 5-8: Moderate; 9-12: Serious)",  
        "language": "text/fhirpath",  
        "name": "score",  
        "expression": "QuestionnaireResponse.item.repetition.answer.valueCoding-extension.valueDecimal"  
      }  
    }  
  ],  
  "version": "1.0.0",  
  "title": "Generalized Anxiety Disorder 7 Item Scale (GAD-7)",  
  "code": [  
    {  
      "system": "http://pubs.bionontology.org/ontology/HBOPIDCT/16458188",  
      "code": "704581007",  
      "display": "Generalized anxiety disorder 7 item scale"  
    }  
  ],  
  "subjectType": [  
    "Patient"  
  ],  
  "contained": [  
    {  
      "resourceType": "ValueSet",  
      "id": "anxietygad",  
      "meta": {  
        "versionId": "1",  
        "lastUpdated": "2018-01-18T09:50:25.165+00:00"  
      },  
      "url": "http://mhof.ml/valueset/MHOFV5004",  
      "Identifier": [  
        {  
          "system": "urn:ietf:rfc3986",  
          "value": "urn:nid:1.3.6.1.4.1.12999.10.1.138"  
        }  
      ],  
      "version": "data.1",  
      "name": "GAD-7",  
      "title": "Generalized Anxiety Disorders 7 Item Scale (GAD-7)"  
    }  
  ]  
}
```

```
{  
  "item": [  
    {  
      "linkId": "anxiety-gad_701",  
      "text": "feeling nervous, anxious, or on edge",  
      "type": "choice",  
      "required": true,  
      "answerValueSet": "http://mhof.ml/ValueSet/MHOFV5004"  
    },  
    {  
      "linkId": "anxiety-gad_702",  
      "text": "Not being able to stop or control worrying",  
      "type": "choice",  
      "required": true,  
      "answerValueSet": "http://mhof.ml/ValueSet/MHOFV5004"  
    },  
    {  
      "linkId": "anxiety-gad_703",  
      "text": "Worrying too much about different things",  
      "type": "choice",  
      "required": true,  
      "answerValueSet": "http://mhof.ml/ValueSet/MHOFV5004"  
    },  
    {  
      "linkId": "anxiety-gad_704",  
      "text": "trouble relaxing",  
      "type": "choice",  
      "required": true,  
      "answerValueSet": "http://mhof.ml/ValueSet/MHOFV5004"  
    },  
    {  
      "linkId": "anxiety-gad_705",  
      "text": "Being so restless that it's hard to sit still",  
      "type": "choice",  
      "required": true,  
      "answerValueSet": "http://mhof.ml/ValueSet/MHOFV5004"  
    },  
    {  
      "linkId": "anxiety-gad_706",  
      "text": "becoming easily annoyed or irritable",  
      "type": "choice",  
      "required": true,  
      "answerValueSet": "http://mhof.ml/ValueSet/MHOFV5004"  
    },  
    {  
      "linkId": "anxiety-gad_707",  
      "text": "Feeling afraid as if something awful might happen",  
      "type": "choice",  
      "required": true,  
      "answerValueSet": "http://mhof.ml/ValueSet/MHOFV5004"  
    }  
  ]  
}
```

- Getting more information than required - overfetching.
- Getting less information than required - Underfetching
- Need for addition HTTP request to get all the required resource - n+1 request problem

Response From REST - Visualisation

Dashboard



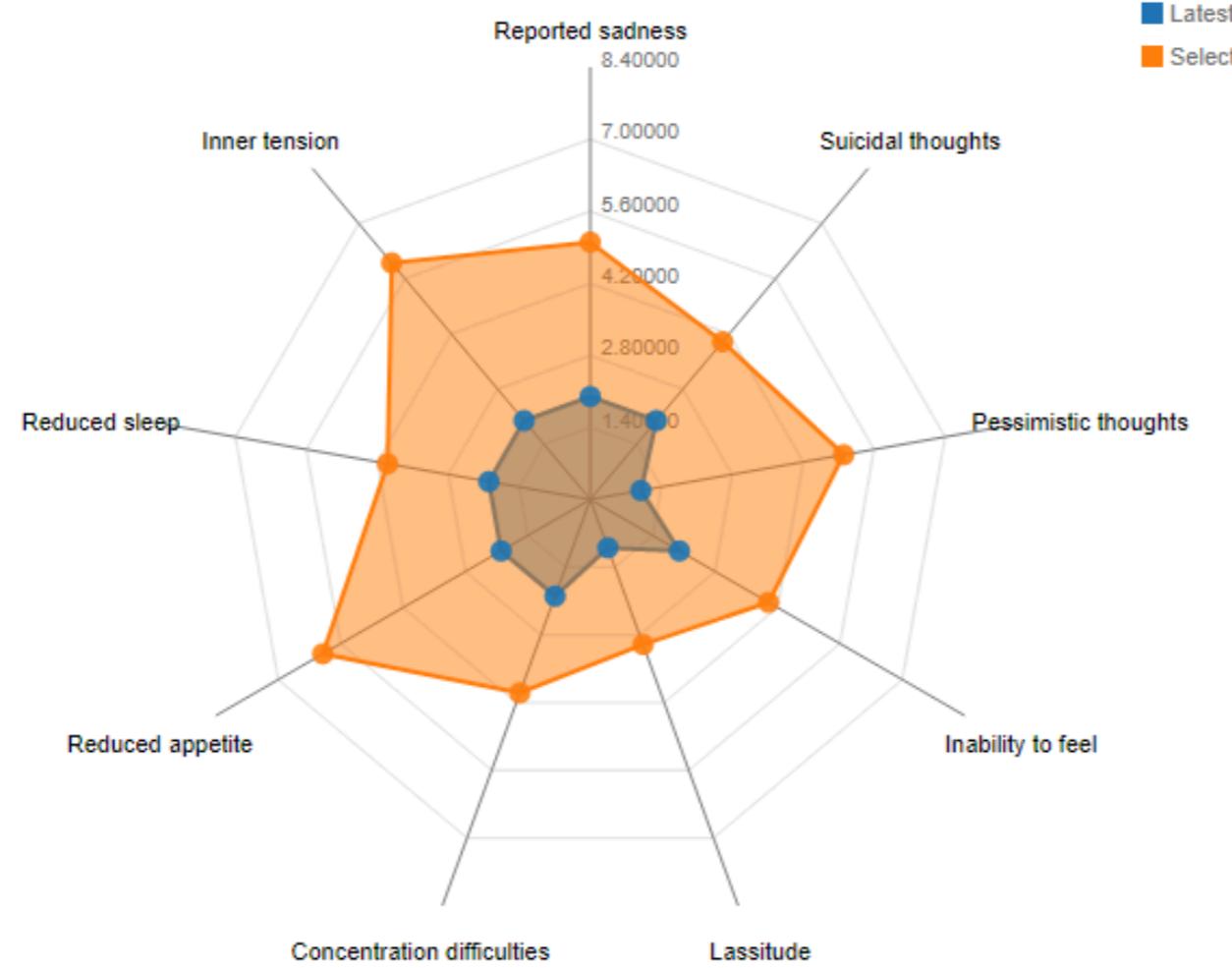
Warnings

Name	Reason
Aaron697 Herzog843	Suicidal thoughts 5
Adrian111 Metz686	Suicidal thoughts 5
Arlette667 Effertz744	Suicidal thoughts 5
Blair400 Langosh790	Suicidal thoughts 6
Calvin845 McGlynn426	Suicidal thoughts 6
Carla633 Sandoval902	Suicidal thoughts 5

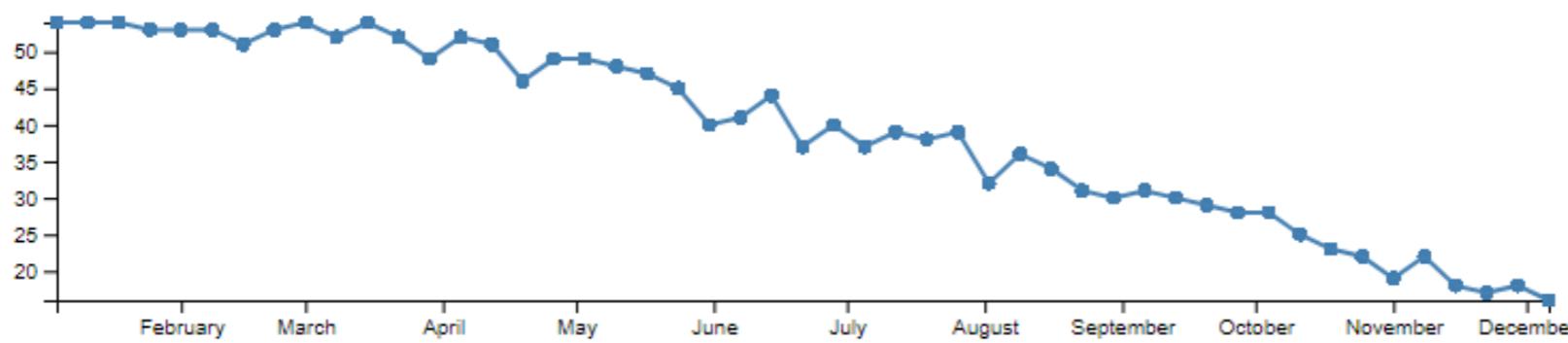
Your patients

Patient Overview						
Name	Time spent in program	Flags	Progression	Last checked	Urgency score	Action
Aaron697 Herzog843	9 months	Suicidal thoughts +2 (5)	declining	1 days	40	View
Adrian111 Metz686	10 months		steady	7 days	35	View
Alfonzo975 Schumm995	6 months		steady	7 days	42	View
Aline709 Mayert710	8 months		improving	7 days	34	View
Alphonso102 Wisoky380	10 months		steady	11 days	33	View
Anisha16 Hartmann983	5 months	Concentration difficulties +2 (5)	steady	5 days	38	View
Annis955 Reinger292	8 months		steady	Never	35	View
Antonia30 Arellano2	10 months		steady	2 months	33	View
Arlette667 Effertz744	7 months		improving	Never	40	View
Aubrey96 Hammes673	11 months		steady	1 months	33	View
Bennie663 Abernathy524	10 months		steady	Never	37	View

Response From REST - Visualisation

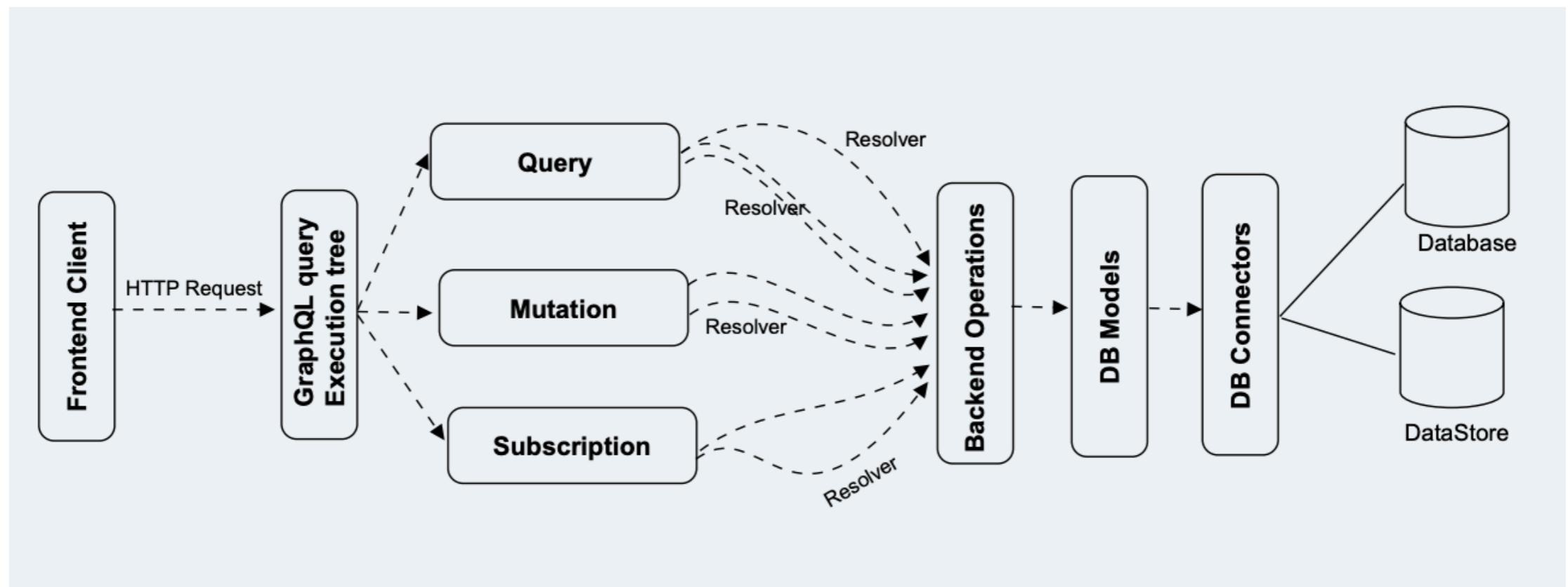


Montgomery And Åsberg Depression Rating Scale

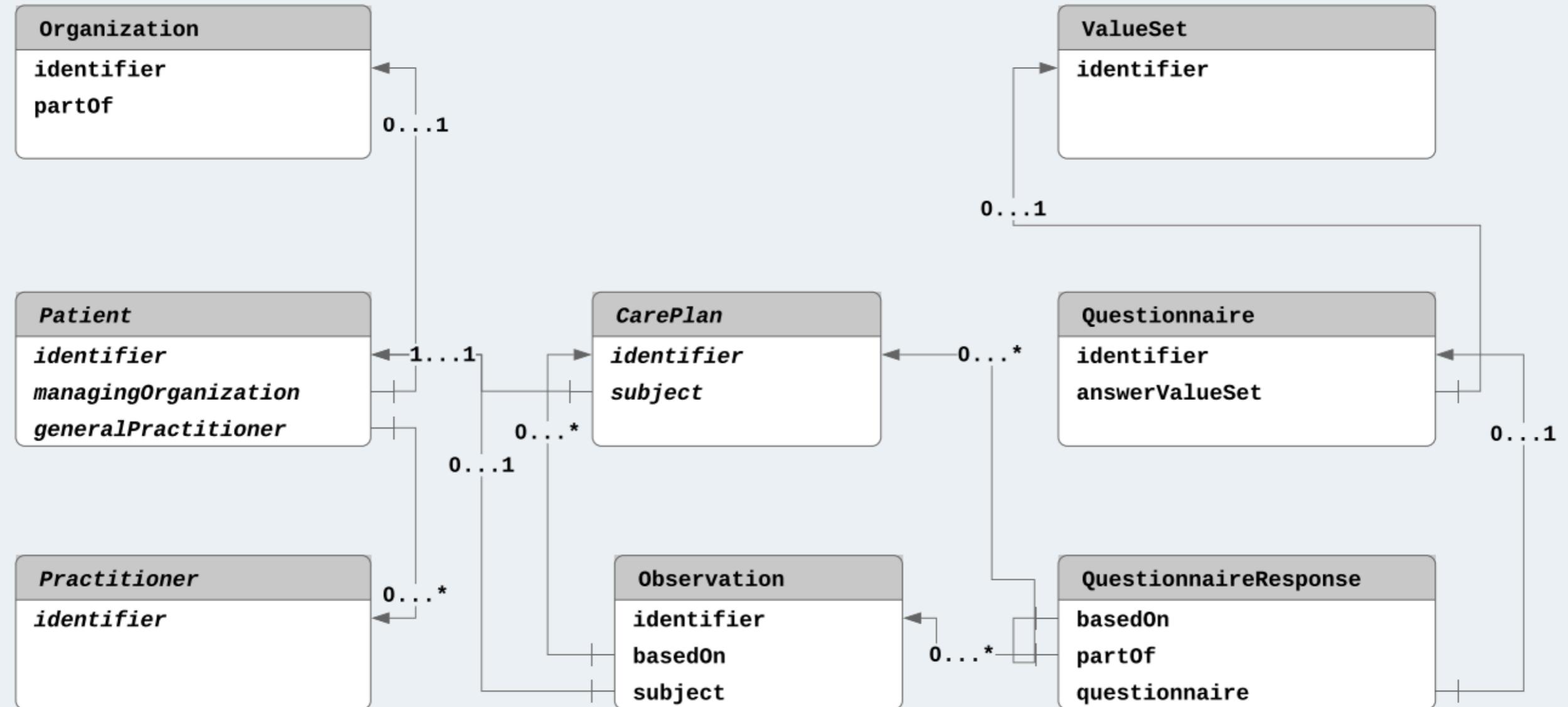


The Solution

GraphQL developed by Facebook and has been embraced users including Coursera, GitHub, Pinterest, Neo4J, PayPal and others.



Current HL7 Resource Support



What is Next?

- Complete SMART on FHIR process
- Support for other required HL7 FHIR resources
- Data Analytics and Business Intelligence for Therapists
- Visualisation Tools
- Explainable AI tools for therapists
- Robust Testing
- Provide Public Access for Testing

Take Aways!



Resources:

- <http://www.mhof.ml/>
- [https://github.com/
sureshHARDIYA](https://github.com/sureshHARDIYA)
- [https://fhir.mhof.ml/
4_0_0/\\$graphiql](https://fhir.mhof.ml/4_0_0/$graphiql)

HL7 FHIR works !

- Interoperability can be achieved.
- RESTful approach might not be best approach to do this. Further research required.
- Further Collaboration is required from Developers and health providers.
- Ready to use solutions Exists but are not scalable.

Thank You !
spørsmål?